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A Summary of Current Program and  
Preliminary Report of Progress

HORTICULTURAL CROPS RESEARCH

of the

United States Department of Agriculture  
and related work of the  
State Agricultural Experiment Stations

Section A

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE  
Washington, D.C.  
December 1, 1967

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CURRENT SERIAL RECORDS



## RESEARCH ADVISORY COMMITTEES

The following Research Advisory Committees were established pursuant to Title III of the Research and Marketing Act of 1946:

1. Farm Resources & Facilities	8. Cotton
2. Utilization	9. Grain and Forage Crops
3. Human Nutrition & Consumer Use	10. Horticultural Crops
4. Marketing	11. Oilseed and Peanut Crops
5. Agricultural Economics	12. Plant Science & Entomology
6. Forestry	13. Sugar
7. Animal & Animal Products	14. Tobacco

The source materials used by the advisory committees include organizational unit progress reports and subject matter progress reports. The latter contain information which was first reported in the organizational reports and has been assembled for use by commodity committees. The number prefixes shown below refer to advisory committees listed above.

### ORGANIZATIONAL UNIT PROGRESS REPORTS

#### Agricultural Research Service (ARS)

- 1 - Agricultural Engineering
- 1 - Soil & Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Consumer & Food Economics
- 4 - Market Quality
- 4 - Transportation & Facilities
- 7 - Animal Husbandry
- 7 - Animal Disease & Parasite
- 12 - Crops
- 12 - Entomology

#### Economic Research Service (ERS)

- 1, 5 - Economic Development
- 4, 5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Economic & Statistical Analysis
- 5 - Foreign Development & Trade
- 5 - Foreign Regional Analysis
- 5 - Natural Resource Economics
- 6 - Forest Service - Research (FS)
- 4, 5 - Farmer Cooperative Service (FCS)
- 4, 5 - Statistical Reporting Service (SRS)

### SUBJECT MATTER PROGRESS REPORTS

- 6 - Forestry (other than Forest Service)
- 7 - Animal-Poultry & Products Research other than Husbandry, Disease and Parasite
- 8 - Cotton and Cottonseed
- 9 - Grain and Forage Crops
- 10 - Horticultural Crops
- 11 - Oilseed and Peanut
- 13 - Sugar Crops
- 14 - Tobacco

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A copy of any of the reports may be requested from Axel L. Andersen, Executive Secretary, Horticultural Crops Research Advisory Committee, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D.C. 20250.

## INTRODUCTION

This report deals with research related to production, processing, distribution, and use of citrus, deciduous, subtropical, and small fruits; potatoes and vegetables; edible tree nuts; flowers and nursery plants; woody ornamentals; and trees for shade and farm windbreaks. It does not include extensive cross-commodity work, much of it is basic in character, which contributes to the solution of problems of other agricultural commodities, as well as horticultural crops. The progress on cross-commodity work is found in the organizational unit reports of the several research divisions of the Department.

This report is organized by problem areas which are shown as the major subjects under the three main divisions in the table of contents. For each of the problem areas there is a statement of (1) the Problem, (2) USDA AND COOPERATIVE PROGRAM, (3) PROGRAM OF STATE EXPERIMENT STATIONS, (4) PROGRESS--USDA AND COOPERATIVE PROGRAMS, (5) PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS.

Research on horticultural crops is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the research agencies of the USDA, and (3) private funds for research carried on in private laboratories or for support of State Station or USDA work.

### Research by USDA

Farm Research comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insects, and crop harvesting, and handling operations and equipment. This research is conducted by the Crops, Entomology and Agricultural Engineering Research Divisions of the Agricultural Research Service.

Nutrition, Consumer and Industrial Use Research. Nutrition and consumer use research pertains to composition and nutritive value; physiological availability of nutrients and their effects; and new and improved methods of preparation, preservation and care in homes, eating establishments and institutions. This work is done by the Divisions of Human Nutrition Research and Consumer and Food Economics Research of the Agricultural Research Service. Utilization research deals with methods of preservation of these commodities through canning, drying, freezing, or combinations of these methods and also with the origination of new forms or combinations of food products. It is also concerned with improved equipment and processes. The work is done by the Eastern, Southern, and Western Utilization Research and Development Divisions; and under contract with State and foreign country laboratories and in cooperation with industry and other organizations mentioned under program for each research area.

Marketing and Economic Research. Research by the Market Quality Division, Agricultural Research Service, deals with the measurement, improvement, and protection of the quality of agricultural commodities in marketing channels. The work encompasses physiological, biochemical, pathological, and entomological problems encountered during the storage, transport and distribution of agricultural commodities, and the development of new methods and devices for evaluation of quality.

Transportation and marketing facilities research is concerned with methods and material used in marketing and transporting farm and food products from the farm to the consumer. This research is done by the Transportation and Facilities Research Division, Agricultural Research Service.

Research pertaining to marketing economics is conducted by researchers in two agencies. The Farmer Cooperative Service deals with the cooperative aspects of marketing. The Marketing Economics Division, Economic Research Service, conducts studies on the physical efficiency and performance of the marketing system with respect to (a) farmers, (b) marketers, and (c) consumers and transportation and interregional competition. Identification and measurement of relationships affecting supply, demand, and price of horticultural crop and commodity situation and outlook analysis are a part of the research in the Economic and Statistical Analysis Divisions, Economic Research Service.

Research on the behavior, opinions, and preferences of consumers which affect their purchase and use of agricultural products or end products is conducted by the Standards and Research Division, Agricultural Research Service.

#### Interrelationships Among Department, State and Private Research

Much of the Department's research is cooperative with State Experiment Stations, various sectors of industry and with growers. Cooperative work is jointly planned and frequently participated in by Federal, State and industry workers. The nature of the cooperation varies with each study. It is developed to fully utilize the personnel and other resources of the cooperators. There is regular exchange of information between State and Department scientists to assure that the research programs complement each other and eliminate undesirable duplication. Many Department employees are located at State Stations and use laboratories and office space close to, or furnished by, the State.

Privately supported research of considerable extent is done by food processors and distributors, food industry and trade associations, food container and equipment suppliers, marketing equipment and facility manufacturers, chemical and fertilizer companies, package and container manufacturers, market research institutes and corporations, nurserymen, orchardists, and

producers. Industry's cooperation in supporting research on horticultural crops in the form of grants, gifts or loans of materials, equipment and facilities at Federal and State Stations has contributed greatly to its success.

A number of food processing companies and wholesale and retail distributors are presently conducting research in various phases of products and process development in frozen, canned, and dried horticultural products. The canning, freezing, and dehydrating industries each maintain an association with a technical staff and either do research in their own laboratories or support research at USDA laboratories, universities, and other organizations. Allied industries and suppliers to the food processing industry maintain excellent laboratories and large research staffs to provide technical information to the industry.

Marketing equipment and facility manufacturers also make sizable contributions to research on the development of equipment for handling horticultural crops on the farm, in orchards, or in greenhouses; into and out of packing houses, transportation vehicles, and wholesale distribution centers; and in the retail establishment. They also conduct research on the containers in which the products are moved and on the transportation vehicles from which it moves from one point in the distribution channel to another. Market research institutes and others in marketing economics research are largely concerned with research in consumer preference, market potentials, market promotion and development, and interregional and intermarket competition.

Chemical, fertilizer, and electrical companies make significant research contributions in the development of new materials, or combinations of materials, to produce more efficiently high quality horticultural commodities, through better plant nutrition; improved disease, insect, nematode, and weed control; and the regulation of growth processes by the use of growth regulator substances and other chemicals, light, and environmental control.

There are a few private breeders of horticultural crops and a number of the larger nurserymen, florists, and seedsmen, who spend considerable time and money in the search for and testing of new varieties in the major production areas, sometimes on their own acreage, but usually in cooperation with some grower. The contribution of growers to our overall research effort on horticultural crops is substantial. Certainly, in the field of production their help is indispensable, for most of the laboratory research results must be finally confirmed by larger-scale experiments. The grower cooperates with the USDA, State Experiment Stations, and suppliers of many materials and equipment, usually without compensation except for the experience and knowledge gained.

USDA and Cooperating Scientists

New Crop Varieties and Breeding Lines Developed. During the period covered by this report, 57 varieties or hybrids and 78 breeding lines were released by the Crops Research Division. Most of these were developed and released in cooperation with State Agricultural Stations and/or other research Divisions of ARS. The releases include inbred lines of germ plasm of interest to plant breeders, both public and private; crop varieties and hybrids of interest primarily to producers and processors of agricultural crops; and ornamental plants and trees of interest to many organizations and citizens, both urban and rural. All of the varieties and germ plasm released are superior in one or many respects including adaptability to mechanical handling, higher yielding ability, better adaptation to environmental hazards, greater pest resistance, better quality for food, industrial or ornamental use, more efficient in utilization of fertilizer and water, or combinations of these attributes.

More New Shrubs for Landscape Use. Breeding programs directed to the production of superior ornamentals for landscape use have resulted in release of six new varieties of hollies, eight viburnums, and four crape-myrtles. These are individually noted for combinations of improved ornamental qualities with increased disease or cold hardiness resistance.

Sex attractants in insects. Progress in research on sex attractants of a number of species of important pest insects continues. Two procedures have been developed for synthesizing the sex pheromone produced by female fall armyworm moths. One of these methods should be adaptable to commercial production of the pheromone. In laboratory bioassay tests this material was shown to stimulate also male gypsy moths.

Two synthetic analogs of propylure, the pink bollworm sex attractant, have been found sexually attractive to male fall armyworm moths. Several homologs of propylure recently synthesized show attraction for male pink bollworm moths.

Eastern Peach Processing Industry Expands. Millions of trees of the new clingstone peach variety "Babygold" have been planted recently in Pennsylvania, New York, Ohio, Virginia, Illinois, Michigan, the Carolinas, Arkansas and Canada. The superior processing quality of this peach was discovered as a result of USDA contract research at the New Jersey Agricultural Experiment Station. A screening of the Station's extensive collection of fruit varieties revealed the commercial value of Babygold. These peaches rate high for making baby food puree, hence their name, and for canning as halves and slices. Eastern growers especially are enthusiastic about the Babygold variety for it promises to make them independent of the fresh market as the sole outlet for their harvest. Arkansas, however, is credited with the first commercial crop--several hundred tons in 1966.

## Commerical-scale Gun Designed for Explosive Puffing of Fruits and Vegetables.

Commerical use of the USDA-developed explosive puffing process for making dehydrated fruits and vegetables is being expedited by the design of a puffing gun for use with a wide variety of fruits and vegetables. The gun employs both injected superheated steam and external heat; residence time in the gun is shortened and output is increased nearly four-fold over earlier models. Pilot plant studies have found it suitable for use (in multiples) for large-scale operations. A local manufacturer has fabricated several for commerical use. The Department engineers who designed the gun have made detailed construction drawings available to industry and have published directions for its installation and operation, together with a detailed cost estimate on quick-cooking carrot and potato dice. The former are presently manufactured commerically by explosive puffing.

Orange Crystals for Instant Juice Used by the Armed Forces. Department scientists in cooperation with the Florida Citrus Commission have developed a new convenience food--foam-mat dried orange crystals that readily dissolve in water to yield a fresh-tasting, nutritious juice. The crystals are made from commercial frozen orange concentrate by a continuous foam-mat dryer process. Since the product is lightweight and has a shelf life of six months at 85° F., it is attractive for commercial export as well as domestic consumption. It also meets the world-wide needs of the Armed Forces, which are currently using about 1,500,000 pounds of orange crystals a year, one-third of which are produced by the new process. They are expected to use up to 5,000,000 pounds as soon as they can be supplied by industry. The potential commercial demand for the product is tremendous, not only for beverages but also for prepared dried foods or other formulations where true fruits are desired but the moisture contained in the fresh product might be a problem. Industry production is expected to increase initially to 20,000,000 pounds of orange crystals a year, equivalent to 5,000,000 boxes of oranges. At \$1.40 a box, this would be an initial annual return to the grower of \$7,000,000.

Aroma Compounds in Delicious Apple Identified. Concentrates of the volatile compounds naturally present in fruit are used for flavoring jams, jellies, and other food products. Their value depends upon their odor strength and the degree to which they retain the natural aroma of the fruit.

In the past, no objective method has been available for measuring either of these characteristics. Department scientists have now identified 50 of the volatile compounds from Delicious variety apples and have shown which ones make important contributions to aroma. Different components contribute different facets of the total aroma: one has a fully ripe or overripe odor, others add a green-apple note. By determining the concentrations of the various compounds, one can now tell both the total strength and the quality of the aroma. Industry will be able to use such analyses for product quality control, for selecting raw material of superior aroma, and even for breeding more flavorful varieties and strains of apples.

Frozen, Quick-Cooking Beans. A process for preparing quick-cooking (10 to 15 min) frozen products from dry beans was developed by Department scientists, supported in part by the California Lima Bean Advisory Board. The cooked beans have natural flavor and excellent appearance. The new products provide consumers with a new type of economical, high-protein, convenience food. Processors can utilize stable, low-cost raw materials; be independent of crop location and harvest time; and utilize surplus space, time and equipment. Products can be produced on demand, minimizing warehousing and transportation costs. Pilot plant production of frozen bean products has been initiated by a leading frozen food processor.

Critical Atmospheres for Storage of Peaches and Nectarines. Research over a period of several years has clearly shown that carbon dioxide concentration is the critical factor in controlled atmosphere storage of peaches and nectarines. Varying the oxygen concentration from 1/2 to 21 percent was ineffective for prolonging storage life without added carbon dioxide. When 5 percent carbon dioxide was added storage life was extended by at least 50 percent at any oxygen concentration from 1 to 21 percent. Internal discoloration, which occurred after 1 month at 32° F. in the absence of carbon dioxide, was completely prevented for 6 to 9 weeks at 32° when 5 percent carbon dioxide was present in the storage atmospheres.

Production of nectarines has been increasing rapidly and will continue to increase. Production in 1954 was less than 20,000 tons. In 1964, it was 75,000 tons with a farm value of \$7,000,000. With increased production, there is need for storage of a considerable part of the production of the late varieties to extend the marketing season. Controlled atmosphere storage appears to be a practical method of avoiding market gluts and extending the period when high-quality nectarines are available to consumers. Preliminary evidence indicates that storage for 8 to 10 weeks is possible at 32° F. if optimum concentrations of O<sub>2</sub> and CO<sub>2</sub> are maintained.

Palletization and Bin Boxes Reduce Costs of Shipping Apples to Overseas Markets. Putting apple boxes on pallets and handling them as one unit instead of handling each individually can reduce the cost of shipping 100 pounds of apples to Europe by \$1.00. Packing, handling and shipping apples in 800-pound bin boxes instead of 42-pound boxes reduces costs even more-- \$2.58 per hundred pounds of apples shipped to Europe. Moreover, fruit pilfered was only one-tenth of that pilfered from shipments of individual apple boxes. If three-fourths of exported U. S. apples were shipped in 42-pound boxes on pallets and one-fourth of the apples were shipped in 800-pound bin boxes, marketing costs would be reduced approximately \$3 million per year.

Citrus Marketing. A study of the possibilities of a group of Florida processing cooperatives coordinating their marketing effort indicates that a central sales organization would materially improve their marketing ability.

Consumer Acceptance of Sweetpotato Flakes. The results of a study acceptance by a panel of consumers of instant sweetpotato flakes, which were developed by the Southern Utilization Research and Development Division, ARS, indicated considerable commercial potential for the new product. This conclusion is similar to that drawn from the results of an earlier study to measure consumer's reactions to instant white potato flakes. The acceptance of the white flakes has been a major contributing factor to halting the downward trend of per capita potato consumption. Since the publication of the final results of the sweetpotato flakes survey, a number of processors have begun producing the sweetpotato flakes.

#### State Agricultural Experiment Stations

Studies on Genetic Variability Aids Bean Breeding Program. The distribution of accumulated dry matter among aerial organs at maturity was studied in New York for 11 varieties of dry beans (Phaseolus vulgaris L.). Harvest indices (percent of aerial dry weight as seed) varied from 53 to 67 percent. Varietal expressions of harvest indices, leaf-area, leaf-area ratios, relative growth rate, relative leaf growth rate, and net assimilation rate were evaluated. This information on genetic variability and the interrelationships of these many factors provides improved understanding of the physiology of yield differences in beans. It also provides a physiological basis for formulating a program of breeding higher yielding dry bean varieties.

Resistance to Ozone Damage in Onion is Related to Ability of Plants to Close Stomates, a Genetic Factor. Researchers in Wisconsin reported resistance to ozone damage to onion leaves is controlled by a dominant genetic system which appears to regulate the sensitivity of the membranes of the guard cells to ozone. In the presence of ozone the membranes of the guard cells in the resistant plants lose their semi-permeability and leak, thereby closing the stomata. The membranes of the guard cells on the susceptible plants are not sensitive to ozone. Apertures remain open allowing ozone to pass into the substomatal cavity causing damage to the surrounding tissue. The damage produced on the susceptible plants was found to be very similar to field type damage produced by natural occurring ozone.

A Physiological and Morphological Study of Rest and Hardiness in Fruit Trees. In studies conducted in Washington, data relating percent survival of dormant Elberta peach fruit buds to temperature were combined by expressing all temperatures as deviations from the temperature required to kill 50 percent of the buds. From these data, a curve relating percent fruit bud survival to temperature was drawn. The shape of the curve obtained by averaging all data for each of three years was constant over the three years. Similarly, averages of all November, December, January, and February data showed the shape of the curve to be constant through those four months.

This relationship can assist in the evaluation of data from field injury on peach bud hardiness. The curve can be used as a standard for comparing data from different locations or years and for comparing percent survival at different temperatures.

Planting and Fertilizing Operations and Equipment. New methods have been developed to permit planting of small seeds. At the New York Agricultural Experiment Station at Cornell, engineers have developed a new planter that uses a tape on which seeds are glued at the desired spacing. At equivalent speeds of four miles per hour, seeds were deposited at spacings of three inches plus or minus two-tenths of an inch. At California, engineers developed a vacuum seed pickup planter that will select and plant single small seeds at regular intervals and reduce the amount of seed required by 90%. The planter will select and pick up single seeds of irregular shape, such as lettuce seeds, and space them in intervals to permit easy thinning by machinery. The new planter reduced labor required to hand thin lettuce fields by 45%.

Crop Harvesting and Handling Operations Equipment. Increased shortage of labor has made it necessary to mechanize harvesting of apples. Research at the Pennsylvania State Agricultural Experiment Station has developed two harvesting machines. One is a picking aid to improve efficiency of hand pickers. The need for ladders is eliminated by keeping pickers on a platform placing them in a better picking position in the trees. The second machine eliminates the need for hand picking. An apple catching frame is placed high in the tree and apples are shaken from the tree onto the frame and conveyed to a bulk box handling scheme with a minimum of damage to the apples.

Water Conservation in Potato Processing. Water usage and management in potato processing plant operations was studied by Maine food scientists. Factors found to affect water use and reuse were: volume of raw materials processed per day; conditions of raw materials at time of processing; loadings of total suspended solids and microbiological populations in effluent waters from various processing steps; and wide variations in processing procedures within individual plants. Consideration for reuse of waters in potato processing plant operations requires evaluation on a continuing basis of total suspended solids, certain soluble solids, microbiological populations, their types, and effect on the finished product as well as other factors. Consideration of reuse of water will also require constant examination to insure that quality and safety of the finished product are in no manner adversely affected.

Texture of Canned Apricots. The effect of calcium and oxalate ions on texture of canned apricot halves was investigated by California scientists.

Calcium ions were found to decrease the movement of pectic materials from fruit to syrup. This might be explained by the ability of calcium ions to bridge between polygalacturonic acid units, thus producing larger molecules which bind cells together at the middle lamella. Added oxalate ions removed calcium from pectin in the cell wall, causing an increase in water-soluble pectin in the syrup and texture softening.

Computer Designs Machine. Confronted with the problem of how to cull bad black walnuts from good ones without cracking them open, Missouri station scientists designed with a computer a theoretical machine that worked when acutally built. The walnut sorting machine was designed after determining many of the physical characteristics of the whole and cracked nuts. To the multi-million-dollar black walnut industry the big saving in tedious hand labor required to separate ban nut meats from good ones is welcome. The machine also saves the cost of handling and cracking bad nuts.

Freeze-Dried Sweet Peppers. Food scientists at the Puerto Rico Station have successfully freeze-dried sweet peppers (*Capsicum frutescens*). The process consists of steam treatment to inactivate enzymes, freeze-drying and packing in jars or cans. Microbial counts are reduced by steam treatments. The freeze-dried product rehydrates readily and retains good flavor. The product is especially useful in those instances in which uniformity and stability of flavor are important.

New Sweetpotato Product. A new sweet potato product that is canned hot and congeals in the can so that it can be removed as a roll has been developed by Georgia Station food scientists. The roll can be made from sweetpotatoes that have been lye peeled, cooked, pureed and mixed with a small amount of dry milk solids. It can be sliced for serving, fried, baked and used in souffle, pies or in other ways. Advantages of processing sweetpotatoes in this form include (a) all sound field-run potatoes harvested, regardless of size and shape, can be utilized; (b) the product is uniform in color, consistency and flavor, and thereby provides uniform serving; and (c) although varieties vary in their suitability for manufacture of congealed rolls, they can be "adjusted" by blending to produce a uniform product.

A New Test for Quickly Determining the Maturity and Flavor of Sweet Corn. Illinois researchers found the maturity of sweet corn at harvest is extremely important to the consumer. Numerous tests such as the "thumb nail" test, moisture content and denisty by immersion in water, are available but these tests are too time consuming or inaccurate. Density determinations of expressed juice can be made in a period of 15 minutes. Density is highly correlated with the vacuum oven moisture. Flavor and density also are highly correlated. Sweet corn processors are now evaluating the density method for their quality control program.

## I. FARM RESEARCH

TREE FRUIT BREEDING AND GENETICS, DISEASES, VARIETY  
EVALUATION, CULTURE AND PHYSIOLOGY

Crops Research Division, ARS

Problem: The fruit industry continually needs new disease-resistant scion varieties with improved horticultural tree and fruit characters and rootstock varieties that are winter-hardy, disease- and nematode-resistant, and which make young trees precocious and more fruitful. More precise information is needed about diseases and their economic control as well as about the basic physiology of fruit setting, fruit thinning, and growth. The best combinations of apple and pear rootstocks and species to induce precocious and reliable fruit bearing are still moot and need comprehensive and systematic evaluation. Valsa canker, a debilitating fungous disease of tree trunks, has been long known and continues to plague peach areas.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, plant pathologists, plant physiologists, and horticulturists engaged in both basic studies and the application of known scientific principles to the solution of fruit growers' problems. Apple breeding research at Lafayette, Indiana, and at Blairsville, Georgia, and cultural and disease research at Wenatchee, Washington, and Arendtsville, Pennsylvania, is cooperative with the respective State Experiment Stations as is pear research at Hood River, Oregon, and Wooster, Ohio. Peach breeding and varietal evaluation research at Fresno, California, is in cooperation with Fresno State College and at Prosser with the Washington Agricultural Experiment Station; disease and cultural research at Clemson is cooperative with the South Carolina Agricultural Experiment Station; at Athens and Experiment, Georgia, it is cooperative with the Georgia Agricultural Experiment Station, and at Davis, California, in cooperation with the California Agricultural Experiment Station. Plum breeding and evaluation research at Fresno is cooperative with Fresno State College and at Prosser with the Washington Agricultural Experiment Station. Cherry breeding and evaluation research at Prosser is cooperative with the Washington Agricultural Experiment Station; and disease research at Logan is cooperative with the Utah Agricultural Experiment Station. Apricot breeding research at Fresno is cooperative with Fresno State College. Federal stations having deciduous fruit-tree research are Wenatchee, Washington; Fort Valley, and Byron, Georgia; and Beltsville, Maryland. Research at Wenatchee includes variety evaluation of pears; disease research with pear, peach, plum, and cherry; and cultural research with apple and pear. Breeding, variety evaluation, and cultural research is done with peach at Fort Valley. Research at Beltsville includes breeding and genetic studies of apple, pear, and peach; diseases of apple, pear, and peach; varietal evaluation of peach; and cultural studies of apple and peach.

The following research is being done under extramural cooperative agreement: biochemical basis of apple scab resistance at the Indiana Agricultural Experiment Station; cause and control of York spot of apple at the Pennsylvania Agricultural Experiment Station; and, at the Georgia Agricultural Experiment Station, winter injury and the short life of peach trees as well as the replant problem and short life of peach trees. Grant research to study the epiphytology of Clitocybe root rot in *Prunus* is done at Stanford Research Institute, Berkeley, Calif.; and contract research to study the biochemical nature of resistance of peaches and plums to bacterial spot is done at Research Triangle Institute, Raleigh, N.C.

Eleven P.L. 480 contracts are currently in effect with the: Osmania University, Hyderabad, India, (1) adaptation of fungi to fungicides; Indian Agricultural Research Institute, New Delhi, (2) maintenance and evaluation of genetic stocks of pome and stone fruits; Israel Ministry of Agriculture, Volcani Institute of Agriculture, Rehovot, Israel, (3) mineral nutrient balance and its application to fruit growing; Department of Plant Pathology, University of Milan, Italy, (4) etiology and methods of controlling pear Moria (pear decline) in Italy; Research Institute of Pomology, Skierniewice, Poland, (5) evaluation of East-European and Asiatic fruit species and varieties recently introduced into Poland which are of value to the U. S., (6) growth regulator effects on stem elongation, bud dormancy, and flower initiation of fruit trees, (7) pome and stone fruit virus diseases in Poland, and (8) mineral element and carbon content of young apple trees as influenced by bearing age; Department of Biochemistry, Institute "Jaime Ferran" de Microbiologia, Madrid, Spain, (9) chemical and physiological changes in fungi during autolysis; Instituto Biologico, Sao Paulo, Brazil, (10) basic biochemistry of crown gall formation; and Institute for Agricultural Research, Sarajevo, Jugoslavia, (11) Sarka (plum pox) virus disease.

The Federal intramural scientific effort devoted to research in this area totals 29.5 scientist man-years. Of this number 5.5 are devoted to breeding and genetics; 14.2 to diseases; 1.1 to variety evaluation; and 8.7 to culture and physiology.

The Federal extramural scientific effort devoted to research in this area totals 3.6 scientist man-years. Of this number none are devoted to breeding and genetics; 3.0 to diseases; none to variety evaluation; and 0.6 to culture and physiology.

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 160.0 scientist man-years is devoted to this area of research.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Breeding and genetics

1. Apple. At Lafayette, Indiana, cooperative research continues with Purdue University on the development of apple varieties resistant to apple scab (Venturia inaequalis). Advanced selections are being tested throughout the United States prior to final selection and naming of varieties.
2. Pear. At Beltsville, Maryland, 14,406 seedlings have now been established in field plantings with the objective of developing high quality varieties resistant to fire blight, Erwinia amylovora. Genetic studies are being conducted on the fruit and tree characters of horticultural importance. Thirty-four advanced selections have been made and 12 are in a grower orchard. Eighteen selections are being evaluated at the University of Missouri.
3. Peach and nectarines. At Fort Valley-Byron, Georgia, two peach varieties were introduced; Sentinel because of bacterial spot resistance and Springold because of extremely early maturity for a yellow-fleshed peach.

At Fresno, the peach variety Fayette was introduced. Eleven other peach and nectarine selections in commercial trial are considered prospective varieties. An additional 28 peach and 49 nectarine selections are considered promising.

At Prosser, 3 peach selections have been distributed for commercial testing and adaptation to other producing areas and one additional promising peach was selected.

At Beltsville, 24 peaches and 2 nectarines were propagated for further testing. Four peaches and one nectarine were distributed for adaptation tests.

4. Plum and apricots. At Fresno, the variety Frontier, a large red-fleshed plum, was released. Four other plum and 2 apricot selections are being tested for commercial possibilities.

At Prosser, 3 apricot selections are in advanced testing stages. All are self-incompatible but cross-compatible with each other and with main commercial varieties. Dullness of the skin due to heavy blush may limit their canning use. Twenty prune-type seedlings were selected for further evaluation.

At Beltsville, 17 apparent hexaploid-diploid hybrids were colchicine-treated to induce chromosome doubling. Leaf areas of higher ploidy were noted and attempts to force mutant limbs from these chimeras are underway.

B. Diseases1. Apple

Apple scab (*Venturia inaequalis*). At Lafayette, Indiana, biochemical studies on the nature of disease resistance continues and there is evidence that resistance is related to changes in cellular permeability of host cell membranes following infection. Initial penetration of the fungus in susceptible tissues is restricted to the intercellular spaces between the cuticle and the epidermal layer.

Powdery mildew (*Podosphaera leucotricha*). At Hood River, Oregon, a change in the surfactant used with Morestan was found to adversely affect the control of powdery mildew. Karathane continues to give the best control on apples. Measurement of mildew conidia collected from apple and pear seedlings showed no differences in size.

Virginia crab decline virus. At Logan, Utah, apple varieties grafted on Virginia crab rootstocks showed moderate growth when the rootstock carried the stem pitting virus but very poor growth when the Virginia crab decline virus was also present. Varieties on Hiberna rootstock showed similar reductions in growth but virus symptoms were absent.

## 2. Pear

Fire blight (*Erwinia amylovora*). At Beltsville, a study of the biochemical nature of resistance reveals that the level of hydroquinone in stem tissues varies between varieties but appears to be consistent when comparing resistant and susceptible varieties. More hydroquinone is found in stem tissues of resistant varieties than is found in susceptible varieties. There are similar differences in leaf tissues but there appears to be less correlation between the resistant and susceptible varieties. Presence of the bacterial organism in host cells does not alter the production or persistence of hydroquinone.

Pseudomonas blight (*Pseudomonas syringae*). At Hood River, Oregon, the relationship of various cultures of *P. syringae* were tested by serological reaction and by pathogenicity. Cultures collected from pear twigs, snap bean, and peach were closely related while those collected from lilac, blackberry, and certain pear isolates showed no relationship.

Pear blister bark virus. At Wenatchee, Washington, the Old Home cultivar was found to be a symptomless carrier of the pear blister bark virus.

Stony pit virus. Fruit symptoms of stony pit were obtained on Bosc, Anjou, Moonglow, and Packham's Triumph cultivars at Wenatchee, Washington, but not on Bartlett, Comice, Dawn, Hardy, Magness, Waite, or Winter Nelis.

Pear decline virus. At Davis, California, Bartlett pear trees on oriental rootstocks showed a stimulation of growth the first year following infection with the pear decline virus.

United States-sponsored P. L. 480 research in Italy adds further evidence to support the fact that "moria" is caused by a virus, transmitted by psyllids. The psyllid species in Italy are apparently less efficient than those which transmit pear decline in the United States. The low percentage of transmission of "moria" with tissue grafts is similar to transmission results with pear decline, and further indicates that the causal virus is poorly distributed in the tissues of affected trees. The poorer efficiency of psyllids in transmitting "moria" experimentally helps to explain the slower spread of the disease in Italian orchards as compared to pear decline in Western United States. Histological effects, including phloem degeneration in the bark, appear to be somewhat unreliable as a diagnostic tool.

Purple leaf curl disease. A purple leaf curl disorder is present in many nurseries in California, and to a lesser degree in the nursery stock in Washington and the East Coast. There is no apparent loss of vigor of the affected trees in the nursery and the effect on production of bearing trees is undetermined.

### 3. Peach

Bacterial leaf spot. At Clemson, experimental bactericide NIA 15005 showed promise of controlling bacterial spot disease of peach when incorporated into the soil early in the growing season. Cross-sectional views of guard cell cuticle configuration of 11 peach cultivars did not provide a clue to the bacterial spot resistance of certain cultivars.

At Beltsville, spray application of the antibiotic oxytetracycline (Terramycin) for the second year gave better field control of bacterial spot on the Rio-Oso-Gem cultivar than any other material tested. Under some conditions, disease control was enhanced by addition of DMSO to the antibiotic spray. In general, no antibiotic residue remained on the fruit at harvest when the last spray was 43-49 days before harvest.

Bacterial canker. At Clemson, it was shown that peach trees are highly susceptible to bacterial canker in November; they are highly resistant in January. There appears to be little difference in the distance bacteria move in peach trees whether introduced in early fall or mid-winter. P. syringae moves primarily through xylem in peach twigs. Bacteriophage typing has been used successfully to aid in following a specific bacterial strain in diseased peach tissue.

Root and crown rots. At Clemson, best root growth of Nemaguard seedlings appeared to be at soil temperatures as much as 20°F. higher than those reported for Elberta seedlings. Resistance of Nemaguard to Pythium irregularare, P. ultimum or Phytophthora cactorum at these temperatures is not known.

At Beltsville, a new program was initiated to study peach root rots in the middle Atlantic area. In surveys of peach feeder roots to date, Pythium spp. were found the most prevalent fungi, P. ultimum was most frequently isolated

from decayed roots on apparently healthy trees, and P. irregularare was present most frequently in decaying rootlets of declining trees. P. vexans and P. rostratum were present in soil but not in roots. Only P. irregularare occurred both in roots and soil. Pimaricin-vancomycin medium was superior to other media in common usage and a juice agar media containing cholestral was useful in inducing reproductive structures for species identification.

#### 4. Plums

Virus diseases. At Sturgeon Bay, additional sources of prune dwarf virus have been found that do not incite symptoms on Buttercup squash. Others incite symptoms on squash but not prune dwarf on Italian Prune.

#### 5. Cherries

X-disease virus. At Logan, results of indexing sweet cherry varieties for resistance to western x-disease virus showed that few have any resistance and some of these are not acceptable because of fruit quality. 'Dicke Braune Blankenburger' does appear to have acceptable resistance, with a high percentage of resistant progeny. 'Long Stem Bing' has less resistance but may be useful in a breeding program. In Washington, 'Bing' cherry on Prunus yedoensis cv. Yoshino developed western x-disease wilt and decline.

Miscellaneous virus diseases. At Wenatchee, the original 'Bing' source tree from which spur cherry virus was isolated was found infected also with apricot ring pox virus. Of 37 sweet cherry varieties tested as possible hosts of spur cherry virus, 11 developed severe symptoms, 6 moderate, 8 mild, and 12 produced no symptoms. Five sour and Duke cherry varieties, and trees of 12 other Prunus spp., were not affected by this virus. 'Early Richmond' and 'Ronald Duke' cherries were found to be symptom-producing hosts of pink fruit virus but 'Montmorency' cherry on P. yedoensis cv. Yoshino appeared to be tolerant of this virus. Of 25 cherry varieties tested in Washington as possible hosts of short stem virus, 8 developed moderate symptoms, 10 mild, 6 slight, and 1 was inconclusive (no fruit). An unidentified virus from cherry in Washington has been characterized on a herbaceous host range and purified from a herbaceous host.

At Logan, six distinct strains of necrotic rusty mottle virus are recognized now. All cherry trees in Utah known to be infected with rough fruit virus were destroyed in 1966. 'Mahaleb' and 'Early Bing' cherries are symptomless carriers of mottle leaf virus. An unidentified disorder was observed on 'Lambert' cherry. Fruit on an affected branch was smaller, narrower, more pointed, had a roughened surface, tended to split along the suture, and was later maturing than fruit on healthy trees.

At Sturgeon Bay, studies with sour cherry and other Prunus species showed some virus separation of the yellows - necrotic ringspot - prune dwarf complex from different parts of the same seed used as sources of virus inoculum for herbaceous plants. Use of gibberellic acid needs to be balanced

with tree fertility to obtain desired improvement of yellows-affected trees.

At Wenatchee, Washington, seedlings of Prunus tomentosa were found to be symptomless hosts of chlorotic leaf spot virus. Chemotherapeutic research at Wenatchee has shown that 4N Physalis floridana synthesizes tobacco mosaic virus with increased virus infectivity, but not titre, through synthesis of more complete virus particles than 2N plants. Inhibition of 8 aza-guanine is due to reduction of complete virus particles from either 4N or 2N tissue. Extracts of 50 plant species inhibited NRSV and extracts of 30 species inhibited TMV from 59 plant species which are "confirmed actives" in anti-cancer tests. Two ALV<sub>2</sub>-inhibiting antimetabolites and an antibiotic affect synthesis of the virus with little change in RNA composition.

At Davis, dilute concentrations of dimethyl sulfoxide appeared to affect the symptomatology of tobacco mosaic in Nicotiana glutinosa.

#### 6. Apricot

Virus diseases. At Davis, all fruit-tree viruses tested caused a measurable reduction in growth of apricot trees, regardless of the presence or absence of foliar symptoms.

#### 7. P. L. 480 Research

United States-sponsored P.L. 480 research in India on adaptation of fungi to fungicides has conclusively shown that certain fungi, particularly, Gloeosporium ampelophagum, the organism of grape anthracnose can develop manyfold greater tolerance to certain fungicides as a result of continuous exposure to them. This fungus was 75 times more tolerant to copper after 15 transfers in culture than initially. The work was prompted by apparent lesser effectiveness of copper sprays in the vineyard. The nature of the resistance is unknown.

United States-sponsored P.L. 480 research in Poland on deciduous fruit tree viruses showed that the reduction of sugar and increase of acid in apple fruits on trees affected by the proliferation disease, the reduction of both sugar and acid in fruits of Prunus on trees affected with sarka disease, the possible multiple cause of Prunus line pattern and evidence indicating viability of Prunus ringspot virus in pollen up to 20 months or as long as the pollen was viable.

#### C. Varietal evaluation

1. Apple. At Blairsville, Georgia, 394 varieties are under evaluation for the Southeastern apple growing region. This is the largest apple collection ever assembled in the area.

2. Pear. The pear collection at Beltsville, Maryland, now contains 838 varieties and 183 accessions of 33 species. These are all being evaluated

for fruit characters and disease resistance.

3. Peach and Nectarine. At Prosser, trees of the peach varieties Dixired, Redhaven, Suncrest, Sunhigh, and a promising selection with tetraploid characteristics were obtained from colchicine treatment.

At Fresno, Jerseyqueen peach produced fruit too small, and Suwanee and Dixiland were unsatisfactory in California. Bud drop was less than 1% apparently due to colder-than-average December temperatures.

4. Sweet cherries. At Prosser, conductivity and callusing measurements of artificially frozen tissues indicate these methods may distinguish varietal difference in hardiness. 'Chinook' rain-cracked worse than Bing, possibly due to different stage of ripening when rains occurred, but 'Rainier' showed good cracking resistance.

5. Apricots. At Fresno, evaluation of Castleton and advanced selections is continuing in state-sponsored canning tests against standard varieties, University of California selections and private-breeder selections.

At Beltsville, nearly all fruit buds were lost to an early frost. Blenril and Superb set light crops and an Oklahoma shelterbelt selection a moderate crop. One Canadian selection bloomed late enough to partially escape.

At Prosser, canning tests of 3 promising selections and standard varieties showed some blush discoloration in the selections. One selection appeared incompatible with peach rootstock.

#### D. Culture and physiology

##### 1. Apple

Nutrition. Following application of differential nutrient solutions on 303 trees in sand culture, major differences in levels of nutrient elements were observed after the first growing season. As measured by leaf analysis, nitrogen, calcium and boron content varied proportionally with the nutrient treatment. Phosphorus uptake was influenced by the source of nitrogen as was magnesium.

A study of the pectin content of healthy and corked tissues has shown that the pectin content is higher in corked tissues but the chain length of the pectin molecules is much shorter. The analyses of cork tissues resulting from mechanical bruising of the fruit was similar to the corked areas of fruit showing the York spot disorder.

Following studies at Wenatchee, Washington, foliar applications of magnesium nitrate sprays are now recommended to the growers as a control measure for magnesium deficiency. Magnesium nitrate is formed in the spray tank by adding 5 pounds  $MgSO_4$  with 5 pounds  $CaNO_3$  per 100 gallons. Foliar applications of  $MgSO_4$  are not effective under the arid conditions of the Northwest.

United States-sponsored P.L. 480 research in Israel to study mineral nutrition balance and its application to fruit growing showed very high levels of calcium and low levels of potassium in nutrient solution reduced growth considerably in apple, peach, apricot, and grape. Mid-shoot leaves are good test organs for plants' mineral status. Under potassium deficiency, all plants examined produced toxic amines identified as putrescine and agmatine.

Rootstocks. The biochemical components of EM IX and EM XVI rootstocks vary considerably and may offer a partial explanation of the dwarfing effect of EM IX. EM IX trees have a less active diamine oxidase system, less phloridzin, phloretic acid, less IAA, and more p-coumaric acid.

Growth retardants. Foliar applications of Alar (n-dimethyl amino succinamic acid) cause a delay in fruit maturity and extend the fruit storage period at Wenatchee, Washington. Treatments of 1,000 and 2,000 ppm extend the storage life of Golden Delicious fruit to the extent that treated fruit stored in common storage is comparable to untreated fruit from CA storage. Foliar applications of Alar on nursery stock reduces the overall height without reducing the stem diameter. This effect will be a distinct advantage to nurserymen and growers alike.

Foliar applications of Alar were found to have a differential effect on fruit size of the Delicious and Golden Delicious cultivars. Applications of 1,000 ppm 3 weeks after bloom reduced final fruit size of Delicious by 13 percent but only 5 percent on Golden Delicious.

Chemical thinners. Research conducted at Wenatchee, Washington, and at two locations in New York, indicate that the most effective time of thinning apples is related to local environmental conditions rather than on "exact" critical time associated with fruit size. Effective thinning occurred during a period of two weeks. With the application of chemical thinners and lanolin paste to various parts of apple fruit and stem, it was found that the chemical thinner SEVIN is most active when it is applied or accumulates at the abscission zone of the fruit stem.

Initiation of senescence. At Wenatchee, Washington, the chemical analyses of leaves from fruit clusters showed significant increases in sorbitol and glucose and increased senescence after the fruit was removed. The presence of fruit retards the loss of protein and chlorophyll from the leaves but removal of fruit induces senescence.

Night temperature effect on developing fruit. Fruit trees were caged at Wenatchee, Washington, and night temperatures were controlled. Night temperatures for the first 21 days after bloom affected color and maturity of the mature fruit but did not affect fruit shape. Cool night temperatures late in the season produced fruit with 60 percent color with 45°F. night temperature, 55 percent color with ambient temperature, and 20 percent color with 70°F. night temperature. The increase in fruit color with reduced night temperature was less than had been expected.

## 2. Pear

Predicting fruit size. Using growth data collected from 6 different orchards during a 7-year period, a standard growth curve for Bartlett pears has been developed at Wenatchee, Washington. At 50 days from full bloom, ultimate fruit size can be predicted within 1/16 inch diameter.

Juvenility. At Beltsville, Maryland, girdling of pear seedlings was found to be more effective in inducing flowering than was scoring. While only 27 percent of the control trees flowered, scoring induced flowering in 40 percent, and girdling induced 54 percent.

## 3. Peach

Rootstocks. At Fresno, a Nemaguard derivative which produces seedlings immune to galling by acrita nematode, also showed better adaptation to alkali conditions as a peach rootstock than did Nemaguard. Nemaguard seedlings appear suitable as rootstock for Japanese plums. F red-leaved seedlings derived from Nemaguard were tested for resistance to <sup>32</sup> root-knot nematodes and show progress in combining this desirable nursery characteristic with resistance.

At Beltsville, the Fresno selection first-mentioned was superior to other rootstocks tested in combined-acrita and javanica resistance. Seedlings of a white-flowered selection give the best resistance to javanica found to date. The latter selections have been hybridized with Nemaguard and the acrita-immune selection.

At Byron, rootstocks for short tree-life and rest-period studies were propagated. Studies on rooting of cuttings are underway to determine methods and type of wood best suited to high yield of clonal rootstocks.

Replant problem. At Athens, Georgia, contract studies by University of Georgia researchers implicate Pythium species as an apparent but not necessarily a primary factor in the loss of feeder roots and decline of peach trees in the Southeast. Recent tests show that chemical weed control and use of fumigants, particularly those with control root rot organisms, decrease losses.

Cold hardiness. At Experiment, Georgia, studies under cooperative agreement have demonstrated most severe damage in 4- to 7-year old trees and this correlates with greater temperature fluctuations of the trunk tissues in this age of trees. Cold injury has been reproduced in bioclimatic full-tree cages. Combined reflective and insulating materials around the trunk reduces the damage.

Chemicals for thinning and breaking dormancy. At Byron, the peach thinner Fruitone CPA, just released, is being reevaluated on 5 varieties. In previous tests under recommended conditions, it has not proved effective on early-maturing varieties.

## PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and genetics

None

B. Diseases

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C. Varietal evaluation

None

D. Culture and physiology

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SMALL FRUIT BREEDING AND GENETICS, DISEASES, VARIETY  
EVALUATION, CULTURE AND PHYSIOLOGY

Crops Research Division, ARS

Problem. Present varieties of small fruits and grapes lack broad regional adaptation suitable for modern commercial use. Needs include large (for ease of picking), firm-fruited (for best handling, etc.), disease-resistant varieties for freezing and for long distance or local marketing, with a sequence of ripening throughout the season. Causal agents of new diseases must be identified, and methods developed for effective and economical control of important fungus, nematode, and virus diseases of berries and grapes, with emphasis on identification and control of viruses in strawberries, raspberries, and grapes. Existing information on environmental factors limiting production and on inter-relationships of temperatures, soil moisture, diseases, and nutrition on plant growth, hardiness, and productivity is inadequate for the cultural practices in propagation and plantation management that will result in high production of good quality fruit and reduced production costs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, plant pathologists, and horticulturists engaged in both basic studies and the application of known scientific principles to the solution of growers' problems. The following research is cooperative with the experiment stations and institutions indicated: European bunch-grape breeding, disease, varietal evaluation, and cultural research at Fresno, California, with the Fresno State College; Strawberry breeding research at Salisbury, Maryland; Willard, North Carolina; and Corvallis, Oregon, with the respective State Experiment Stations; and in addition, strawberry breeding and cultural work at Carbondale, Illinois, with Southern Illinois University; Raspberry and blackberry breeding research at Corvallis, Oregon, and Carbondale, Illinois, with the Oregon Agricultural Experiment Station and Southern Illinois University, respectively; Blackberry cultural research at Corvallis, Oregon, with the Oregon State Agricultural Experiment Station; Blueberry breeding research at Gainesville, Florida; Tifton, Georgia; Jonesboro, Maine; and Ivanhoe, North Carolina; and breeding and disease research at Hammonton, New Jersey, and Raleigh, North Carolina, with the respective State Experiment Stations; Cranberry breeding research at East Wareham, Massachusetts; and disease research at New Brunswick, New Jersey, with the respective State Experiment Stations.

Breeding research (strawberries and raspberries) is done at the USDA Horticultural Field Station, Cheyenne, Wyoming. At Beltsville, Maryland, breeding, variety evaluation, and disease research is done with Eastern bunch grape, strawberry, blackberry, blueberry; and cultural studies are done with the Eastern bunch grape, blueberry, blackberry and strawberry.

Grant supported research on the biochemical nature of resistance of strawberries to red stele fungus is done at Boyce-Thompson Institute, Yonkers, New York; and on strawberry resistance to mites is done at Lexington, Kentucky, cooperative with the Kentucky Agricultural Experiment Station and jointly grant supported by the Crops Research Division and Entomology Research Division.

The following research is being done under extramural cooperative agreement: Improvement of blueberries at the New Jersey Agricultural Experiment Station; and Inheritance of cane canker resistance in blueberries at the North Carolina Agricultural Experiment Station.

Two 5-year P.L. 480 contracts were initiated: (1) with the Research Institute of Pomology, Skiernewice, Poland, physiology and biochemistry of fruiting in strawberry; and (2) with the Agricultural Institute of Slovenia, Ljubljana, Yugoslavia, to collect and evaluate indigenous wild fruits and breed small varieties with a high vitamin-C content.

The Federal intramural scientific effort devoted to research in this area totals 13.0 scientist man-years. Of this number, 5.8 is devoted to breeding and genetics; 5.5 to diseases; 1.3 to variety evaluation; and 0.4 to culture and physiology.

The Federal extramural scientific effort devoted to research in this area totals 2.0 scientist man-years. Of this number, 0.3 is devoted to breeding and genetics; 1.3 to diseases; and 0.4 to culture and physiology.

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 70.0 scientist man-years is devoted to this area of research.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and genetics

###### 1. Grape

American bunch grapes. The principal objective is breeding for disease resistance, especially black rot, to eliminate or reduce the need for stratification of grape seed showed that a heat treatment, either wet or dry, or cold water extraction does not overcome inhibition of germination. These treatments are helpful on partly after-ripened seeds but did not appreciably increase germination of freshly harvested seed. Two new varieties were introduced for use as local market and home garden types. Rosebelle is a large fruited, productive, very good flavored, red variety. Bluestar is a black variety, which is also large fruited, productive, and good flavored. Both ripen in midseason.

European bunch grapes (Vinifera). The principal object is breeding seedless varieties for table use and for raisins. Twenty selections have been propagated for wider testing, and four selections were placed in commercial trials for the first time. An earlier selection in grower trials, F32-141, is a very early, large-berried grape that is particularly outstanding.

2. Strawberry. Origination of disease resistant varieties is the major objective in the breeding work at Beltsville, Salisbury, Carbondale, Corvallis and Willard. At Willard, 5 large-fruited strawberry selections have been propagated for replicated tests at 4 locations in North Carolina and for extensive tests in nearby states. Fruit and disease ratings taken in 1966 among progenies and among selections indicated that some selections are highly resistant to leaf spot and leaf scorch.

Low temperatures at blossom time at Beltsville did extensive damage to strawberry plants despite irrigation protection but 4 selections continued to appear promising as potential varieties: Md-US 2915, Md-US 3068, Md-US 3079 and Md-US 3184. A more recent selection, US 4419, with red stele resistance that ripens very late is promising. In an extensive screening of selections to races A-1, A-2, A-3, A-4, A-5, and A-6 several promising selections were highly resistant to all the races except A-5.

At Corvallis, strawberry selection, US-Ore 2331, was named Vale and released for use as a fresh market and garden variety for eastern Oregon, eastern Washington and western Idaho. Preliminary selection work was done in evaluating strawberry clones having characteristics that could be utilized to originate varieties for mechanical harvest. US-Ore 2785 and US-Ore 2786 are being tested extensively as potential new varieties.

3. Raspberry. Raspberry breeding at Carbondale and Corvallis continue to emphasize breeding for disease resistance. At Carbondale, the NC 223 red raspberry that was placed on cooperative tests in 10 states three years ago appears promising as a potential new variety for raspberry production in southern United States. At Corvallis, of 18 varieties and selections that were canned and frozen for quality evaluation US-Ore 1308, 1314 and 1319 are well suited for freezing. None of the selections in yield tests yielded more than existing commercial varieties. Some, however, appear resistant to root rot.

4. Blackberry. At Carbondale, Corvallis, and Beltsville, origination of thornless winter-hardy blackberries that ripen over an extended period of time are the main purposes of the work. At Beltsville, the new varieties, Smoothstem and Thornfree, survived the winter of 1966-1967 with slight or no damage when other thornless blackberries were killed to the ground and some of the thorny varieties had cane damage from winter injury. One newer selection, the US 1526, is also hardy and appears promising as a potential variety.

At Carbondale, SI US 84 yielded at the rate of 12 tons per acre in comparison with Darrow at 5 tons, and Raven at 4-1/2 tons per acre. The genomes of

Burbank thornless (2X) and Early Harvest (2X) were found to differ by at least one and possibly two chromosome translocations. A colchic平ploid 4X form of Early Harvest proved to be almost completely apomictic. In a genetic study of inheritance of thornlessness from the Whitford Thornless (2X) early results indicate that the character is recessive but differs from that of Merton Thornless and Burbank Thornless by being multigenetic and having a suppressing action on prickle production.

The US-Ore 1063 thornless blackberry selection appears promising in Oregon and Washington because of its winter hardiness.

5. Blueberry. Major objectives remain unchanged but increased emphasis is being given to interspecific hybridization, breeding for cane canker resistance, and breeding for consistent yearly yields. In New Jersey the Lateblue variety was named and released. This is a late ripening variety with uniform fruit size that ripens a high percentage of its fruit at one time and appears particularly well adapted to mechanical harvesting. Four other selections appear promising as potential varieties.

In North Carolina, five selections appear particularly promising that are resistant but not immune to cane canker. Seventeen of the older rabbiteye selections appear promising. In Florida, ten selections that have low chilling requirements have been propagated for extensive testing. In Maine, three selections that had been made previously appear promising because of their winter hardiness and productiveness. In Georgia, of the older rabbiteye selections 3 are being propagated for possible variety release. In Michigan, 3 of the older selections appear promising as potential varieties because of their winter hardiness and productivity. These are E-22, E-36 and E-176, ripening from very early to late mid-season. These 3 are being propagated for extensive testing and possible introduction. At Cheyenne, Wyoming, third-year yields were obtained on Radiance and 4 advanced Cheyenne selections at Torrington that indicated that the 56373-7 was nearly twice as productive as Radiance.

#### B. Diseases

##### 1. Grape

Virus diseases. At Beltsville, single callus cell cultures from virus infected vines were obtained grown to form large cell masses but none of these developed into organized plant growth. A species collection has been assembled and will be graft inoculated with several strains of leaf roll virus to see if any will serve as useful indicators under eastern conditions.

In California, 8 viruses occur that are detectable by proper indexing methods. The effects of virus complexes, establishment of virus free stocks, and heat treatments for inactivation of viruses, are the main objectives of the research work. By differential heat therapy, vines have been obtained during the past year which are free from leaf roll but are still infected with corky

bark virus, indicating that these are separate and distinct viruses. During the past year heat treatment was used to obtain clean stocks of the balance of the major grape varieties and these are being established in the foundation vineyard at Davis. Plants of 14 registered rootstocks and 90 registered scion varieties with a total of 875 individual vines are now planted in the foundation vineyard at Davis in the California Grape Certification Program. Herbicide treatments indicate that 2,4-D Amine applied as a foliar spray to grape vines in mid September at the rate of 4 or more pounds of actual 2,4-D per acre gives the best kill of roots in the soil. Killing of roots of fanleaf infected vines prior to pulling the plants has greatly reduced the reservoir of fanleaf virus in the soil.

## 2. Strawberry

Virus diseases. At Beltsville, 56 plants were freed from virus by using heat-treated tip-cultured technique. Eight plants are still in culture with insufficient roots to transfer to soil. High losses through necrosis of tip cultures in the past was found to be due to the sodium hypochlorite dip. Elimination of the dip has resulted in 60 cultures with no fungus or bacterial contamination and no necrosis of tissue. Indexing of tip cultures that were established in soil has shown that crinkle, latent A and latent C viruses can be eradicated through this method. A virus from the variety Louise, which appears to be veinbanding, is very persistent. A clone of F. vesca from Moldavia, USSR, was found to be free of detectable viruses and to be an excellent virus indicator, especially for crinkle viruses. This clone has been propagated and distributed to investigators working with strawberry viruses.

At Corvallis, Oregon, several strawberry plants that appear virus free have been obtained by excision of tips from stolons that had been soaked in 5-mercaptopropyl uracil at 5,000 ppm, and 2,5 di-amino-4-6 pyrimidinedione at 2,500 ppm. The stolons were originally infected with mild yellow edge virus. Virus free plants were obtained from plants infected with mild yellow edge and crinkle virus when the infected plants were heat treated at approximately a month at 100°F and axillary crown buds excised within 2 weeks after treatment. Pretreatment prior to heat treatment of strawberry plants with hydrazine sulfate at 8,000 ppm raised the heat tolerance of strawberry plants, but the virus was not inactivated. When 114 selections from the breeding work were inoculated by grafting with a complex of crinkle, mottle and mild yellow edge virus only the US-Ore 3044, 3050, 3087, 3107, 3051 and 3137 were tolerant. When mottle virus was inoculated into virus free Northwest plants, very little reduction in runner production occurred but when combinations of pairs of mild yellow edge, crinkle and mottle viruses were introduced there was a marked reduction in runners. When seedlings were grown in the field at Aurora and at Corvallis for 2 years and selections indexed for virus, 80% and 35%, respectively, of the plants were infected.

### 3. Raspberry and blackberry

Virus diseases. Detection and identification of raspberry and blackberry virus diseases and the development of virus free stocks continue as major objectives in the work. In raspberry viruses about 3 percent of seedlings from a cross of New Logan x Plum Farmer were found to be infected with chlorotic leafspot virus that resulted from seed transmission. None of the seedlings had New Logan virus which indicates that it is probably not seed borne through the egg but it is known to be transmitted through pollen. A virus tentatively designated as New Logan virus that is latent in black raspberry and red raspberry varieties was found to have spread into Latham stocks from an adjacent planting of infected Bristol black raspberry. This is the first evidence of natural field spread of NLV. Pollen from infected New Logan flowers when crushed and applied to Chenopodium quinoa was found to be viruliferous. New Logan virus is heat stable in raspberries but has a thermal end point in C. quinoa sap of 55 to 60°C. In vitro at 5°C NLV remains infectious for more than 2 weeks. Partial purification was accomplished with NLV from C. quinoa by proper manipulation of methodology which produced virus preparations of low titer and low titer antisera was developed in rabbits. NLV was found to be unrelated to a number of isometric viruses or to Prunus necrotic ringspot virus or to raspberry mosaic viruses.

Isolation of a Phytophthora that has been identified as P. megasperma Drechs. is associated with a root rot of red raspberry in the Pacific Coast area.

Experimental systemic compound, Temik, was tested for its ability to control powdery mildew and mites on raspberries. In infected Latham red raspberries of powdery mildew was not controlled at any dosage but mites were controlled for a month at 6 lbs. actual Temik per acre.

### 4. Blueberry and cranberry

Virus diseases. Surveys in New Jersey indicate rapid spread of red ringspot virus in some fields. No vector of the virus has been found as yet but surveys indicate that the vector may be a soil borne culprit. Trichodorus christiei has been found in soils where plants are infected with red ringspot virus. Growing blueberry nursery plants in methyl bromide fumigated soil and spraying with DDT and parathion throughout the 1965 and 1966 growing seasons appears to have greatly reduced or eliminated spread of red ringspot virus in the nursery.

Fungus diseases. In a study of the cane canker fungus in relation to development of a screening technique for breeding material, 14 isolates were grown on 5 different substrates. Pycnidial production was best on oatmeal agar for all isolates. Isolates varied in the quantity of spores produced by as much as 40 times. Canker free blueberry plants of 16 varieties were inoculated with 8 different isolates of the Botryosphaeria corticis and infections resulted in all instances. The number of lesions formed on the different varieties varied among varieties and among isolates.

### C. Variety evaluation

Grape. Rootstocks. Phylloxera and nematodes are becoming increasingly important problems in grape production and this has increased the interest in the use of grape rootstocks. In three different vineyards last year, Emperor vines on Harmony rootstock (the new rootstock introduced by the Fresno station) outyielded those on the commonly used 1613 rootstock with no reduction in color or attractiveness of the fruit, such as has been associated with 1613. In Thompson Seedless tests, vines on Harmony outgrew and outyielded those on 1613 rootstock. Rootstock selection 91-102 selected in 1957 demonstrated a slight benefit over Harmony rootstock in increasing the vigor of Thompson Seedless vines.

### D. Culture and physiology

#### 1. Grape

Propagation. At Fresno, in some grape propagation work, an asphalt protective coating was substituted for field mounding of budded grape vines. Survival under the emulsion was inferior to mounding except with machine grafting where a nearly perfect fit of bud and stock gave good survival with the emulsion coating. In a test of packaging materials for callusing bench grafted cuttings, peat moss stimulated the development of more callus than sphagnum moss or newspaper wrapping. When callused bench grafts were hardened off for three months in a refrigerator and then subjected to freezing temperatures for one-half hour the survival at 28°F was equal to non-frozen controls but 26°F damaged the grafts and only a few survived at 24°F.

#### 2. Blueberry

Pollination. In a preliminary study at Beltsville to determine whether pollination is a factor in unproductiveness of varieties, Blueray was found to mature larger fruit with less seed per berry than Earliblue which is usually an unproductive variety. Berry size of Blueray with the fewest number of seeds was larger than that of fruit size of Earliblue with the largest number of seeds. When flowers of Earliblue and Blueray were pollinated with different quantities of pollen the fruit set increased as the quantity of pollen increased, especially with Earliblue. In a comparison of the seed content of fruit of 4 varieties picked at random the fruit of Earliblue had 26 seed per berry, Coville 32, Blueray 44 and Bluecrop 55. Blueberry pollen was found to be viable at 12 months storage when held at 40° in a petri dish.

Seed germination. Seed germination studies revealed that seed held in the dark did not germinate whereas that in the light did.

#### 3. Strawberry

Fruit development. United States-sponsored P.L. 480 research, in Poland, on

the physiology and biochemistry of fruiting in strawberry showed that potassium, sodium, and phosphorus move toward and into the fruit mainly because of suction power of fruit rather than in the transpiration stream.

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CITRUS AND SUBTROPICAL FRUIT BREEDING AND GENETICS,  
DISEASES, VARIETY EVALUATION, CULTURE AND PHYSIOLOGY

Crops Research Division, ARS

Problem. Precise information is lacking about the interrelation between climatic factors and growth, cold hardiness and production; on the absorption processes and functions of various elements needed in growth and the effects of soil salinity, alkalinity and high water retention on growth; on the biochemistry of citrus metabolism and the effects of air pollutants on metabolism and growth; on various diseases and methods to control them. Currently used rootstocks do not induce enough cold hardiness in tops, are seriously affected by diseases and nematodes, are not tolerant enough to high soil alkalinity, salinity, and poor drainage and do not induce high-enough yields of high quality fruit. Present scion varieties generally lack cold hardiness, disease resistance, fruit quality, widespread season of maturity, and are unsuitable for both fresh market and processing.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program involving plant pathologists, physiologists, horticulturists, and plant breeders carrying on both basic and applied studies to enable growers of dates, avocados, and citrus to increase both production and quality. Citrus research is done at the Federal stations, Orlando, Florida; Weslaco, Texas; and Indio and Brawley, California; date breeding, disease and cultural research is done at Indio; and avocado disease and cultural research is done at Weslaco. Citrus hybridizations are made at Orlando and Indio but not at Weslaco and progenies are evaluated at all three locations; disease studies are carried on at all three Federal stations; basic physiology studies of cold hardiness are centered at Weslaco, with variety and hybrid progenies evaluated for cold hardiness at all three stations; rootstock evaluation on a field basis is centered in Florida but preliminary evaluation of hybrid rootstock progenies and certain species for cold hardiness, salt tolerance, and disease resistance is carried on at all three stations; basic nutrition is carried on principally in Florida but some work is also done in Texas and California. Climatology research is carried on in Florida, Texas, Arizona, and in several locations in California; the work in Arizona and California is in cooperation with the Agricultural Experiment Stations.

Eight 5-year P.L. 480 contracts are currently in effect with the: Indian Agricultural Research Institute, New Delhi, (1) citrus dieback in India; Department of Agriculture, University of Calcutta, Calcutta, India, (2) chemicals to increase fruit bud formation and overcome alternate bearing of mango, and (3) chemicals to improve methods of vegetative propagation; Israel Ministry of Agriculture, Volcani Institute of Agricultural Research, Rehovot, (4) new methods for assessing nutrient status in citrus trees and other plants, (5) the physiological basis of tolerance of horticultural

crops to cold, drought, and water stress, and (6) develop a method for rapid propagation of superior date varieties; Plant Virus Research Laboratory, Ministry of Agriculture, Cairo, Egypt, (7) for citrus virus research; and Instituto Biologica, Sao Paulo, Brazil, (8) interference between strains of tristeza virus.

The Federal intramural scientific effort devoted to research in this area totals 18.0 scientist man-years. Of this number, 3.5 is devoted to breeding, 5.0 to diseases, 0.3 to variety evaluation, and 9.2 to culture and physiology.

There is no Federal extramural scientific effort devoted to research in this area.

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 88.0 scientist man-years is devoted to this area of research.

#### PROGRESS--USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and genetics

1. Citrus. At Indio, a superior sour orange and a hybrid of sour by Rangpur lime that produces nucellar seedlings equal in salt tolerance to Cleopatra mandarin were selected for further trial in Florida and Texas.

A large amount of variation in development occurs among ovaries of the Clementine tangerine at pollination and at any given time following pollination.

Results of backcrossing and selfing Temple orange clearly indicate that it should be classified as a mandarin orange (Citrus reticulata).

##### B. Diseases

###### 1. Citrus

Fungus diseases. The Australian sour orange, in tests at both Indio and Orlando, showed superior *Phytophthora* tolerance to other selections of sour orange. Combinations of DMSO and tribasic copper show promise in foot rot control of lesions on large trees. Also, captan at 1/2 lb per 100 gallons of water will prevent infection of nursery stock. P. parasitica and P. citrophthora have been recovered from roots, whereas only P. parasitica was recovered from trunk lesions.

Virus diseases. Long-term cooperative experiments emphasize the serious economic effects of stubborn disease on the growth and yield of grapefruit and orange trees. Improved indexing techniques aid in the detection of stubborn disease. Zinc and manganese deficiencies are apparently caused by stubborn disease. Shoots with "poplar-leaf" symptoms are a more

consistent source of stubborn virus than shoots with normal leaves. Apparent greening symptoms (as confirmed by Schwarz of South Africa) have been found on citrus in Florida. Propagations of 10 citron clones and seedlings of red-fruit Rough lemon selection provided suitable index plants for yellow-vein virus without the use of vein-enation virus to synergize the reaction. Two citron selections expressed symptoms of yellow-vein and exocortis viruses independently. *Citrus macrophylla* is susceptible to cachexia and should not be used as rootstock for budlines known to carry, or suspected of carrying, the cachexia virus. The sporadic distribution of tatter leaf symptoms and the virus in citranges appear to result from a recombination of factors controlling immunity in one parent (trifoliate orange) and susceptibility in the other (sweet orange). The exocortis virus can be mechanically transmitted as a contaminant on budding knives, although it was not readily transmitted by sap-inoculation of leaves.

United States-sponsored P.L. 480 research in India reveals that citrus dieback is caused by "greening disease" virus rather than tristeza as earlier suspected. The determination of "greening" as a cause makes the problem more serious because there are no satisfactory control measures for the "greening disease". Similarly sponsored research in Egypt on citrus viruses suggests that safargali (stubborn) disease may be transmitted by the primitive chrysanthid fungi that are known to be virus vectors in several plants. The final report of P.L. 480 research in Brazil on the interference between strains of tristeza virus showed that citrus can be protected against severe strains of tristeza by immunizing plants with mild strains. This project has developed information for practical control of tristeza in areas where the disease is universal and citrus culture must be able to exist in the presence of tristeza.

Diseases of undetermined cause. The cause of mandarin decline is being investigated in California. Rio Grande gummosis symptoms on grapefruit in Florida have been associated with high potash fertilizer applications.

## 2. Date

Fungus diseases. Fungi resembling *Rhizoctonia* are pathogenic on germinating date seeds. Among 6 species of fungi used in inoculation studies, only *Rhizoctonia* sp. damaged seedling roots in the absence of nematode injury.

Nematodes. Root-knot nematodes (*Meloidogyne javanica*) were the primary and principal cause of damage to roots of date seedlings.

## C. Variety evaluation

1. Citrus. The Page, Nova, and Lee varieties need pollinizers to set a good crop. The best pollinizer for Page is Lee, as it not only induces a good fruit but also increases fruit size. Orlando makes a suitable pollinizer for the Lee and Nova varieties.

## D. Culture and physiology

### 1. Citrus

Rootstocks. In tests of rootstocks for orange, grapefruit, and tangerine in Coachella Valley the highest yields were on Citrus macrophylla, but on Rough lemon yields were nearly as great and fruit size and quality were better. Recovery of Meyer lemons in Texas from frost injury was better if the tree had been planted with the bud union buried so that scion rooting occurred than if no scion rooting occurred. Mandarins used as rootstocks for Valencias in Texas showed the best freeze recovery based on yields. Nucellar Redblush grapefruit have shown lower yield recovery on all rootstocks than old-line Redblush on the same rootstocks. In Florida intermediate stem pieces of Rough lemon and sour orange did not change scion-rootstock variety performance. Among rootstocks that exhibit dwarfing characteristics are: Savage and Rusk citrange, Citrumelo C-4481, Capuchin, Honey orange, Yu Tse pummelo, Misri Batabi, and trifoliate orange.

Mineral nutrition. The time of application of N to grapefruit on the Ridge in Florida has no effect on yield and only slight effect on quality. Yields, however, have increased with N rate regardless of when N is supplied.

In Israel, P.L. 480 research on new methods for assessing nutrient status in citrus and other plants developed an interesting new approach to determine minor element deficiency in citrus leaves, particularly molybdenum, using enzyme assays rather than conventional mineral element content or yield analyses. The researchers establish procedures to extract and assay nitrate reductase, a molybdenum-dependent enzyme. The ratio between induced potential and actual enzyme activity is a measure of molybdenum deficiency even in cases of incipient deficiency not yet visible.

Salt tolerance. In a pot-culture experiment shoot growth of citrus was not appreciably reduced by salinity until after about 1% of chloride had accumulated in the leaves. This result suggests that growth was limited by toxic rather than osmotic effects.

Cold hardiness. Photosynthetic fixation of  $\text{CO}_2$  by frozen leaves is completely inhibited 30 minutes after thawing, and all chlorophyll destruction results within 3 to 6 hours after thawing. However, the metabolism of U-C<sup>14</sup> sucrose in the citrus leaf was unaffected by freezing. Water soaking of the leaves occurs as ice is formed during freezing and appeared to result from the movement of water from the cell to the intercellular spaces during freezing. Citrus trees exposed to hardening temperatures in the absence of light did not cold-harden as compared to those in light. Trees exposed to hardening temperatures hardened more at low humidities than at high humidities. Forty-one citrus and hybrid varieties and selections were tested for cold hardiness. The Orlando, Lee, and Page were among the most hardy. Decenylsuccinic acid did not increase the cold hardiness of citrus seeds exposed to subfreezing conditions. Resistance measurements of citrus

trees provide a rapid means of determining differences in the cold hardiness of varieties. In freezing tests of hybrids, 1 family of seedlings was found to be as cold hardy as Changsha; 1 hardier, and 4 less hardy than Dancy.

Drought tolerance. Israeli P. L. 480 research on the physiological basis of the tolerance of horticultural crops to cold, drought, and water stress showed interesting relationships between drought resistance and senescence. Inhibitors of protein synthesis hasten the breakdown of RNA. The activity of polyphenoloxidase decreases, whereas, the activity of Rnase increases under stress conditions. Older leaves showed less response to water shortage than did younger leaves. In senescence it is assumed that most of the metabolites in the tissue have gone to completion products such as cellulose, protein, starch, lignin, etc. and that the cells have a higher bound water content. Such tissue is known to have and would be expected to have less response to water shortage.

Biochemistry. Decenylsuccinic acid (DSA) treatments inhibit oxygen uptake and catalase and peroxidase activity by roots, leaves, and fruit rind of Pineapple orange. Girdling of grapefruit trees had no lasting effect on malic and citric acid contents in fruit. The rate of catalase activity in leaves of citrus showed a rapid drop after a 2-hour exposure of leaves to 28°F for 2 hours and remained depressed from 3 to 9 days. Catalase activity is present in the pulp of fruit of most citrus varieties until the time of juice accumulation, but in the low acid-type citrus, catalase activity is quite high for several months after time of juice accumulation.

Growth regulators. Initial trials reveal that ascorbic acid will induce abscission of Pineapple and Valencia oranges without causing defoliation. However, the treatment causes a fruit pitting.

Climatology. A relatively new solid fuel heater indicates adequate heat potential, easy handling in the field and quick lighting. Excessive smoke plus less than 5 hours of effective burning time are unfavorable characteristics. High electrical potentials appear to protect trees from low temperatures, and automation in field data collection and recording continues to be functional but not without minor problems. No large major freezes occurred but local radiation freezes did considerable damage, especially to young trees in the western and southwestern parts of central Florida. Effects of scions-rootstocks were mostly indistinguishable. A record late freeze occurred on February 25-26, 1967. Damage was mostly to new growth. The effect of high temperatures on citrus was observed in the field at Indio. Air movement, transpiration, irrigation, and clouds affect the leaf, stem, and fruit temperatures. White-washing fruit prevented most of the injury to fruit from sunburn.

## 2. Dates

Fruit thinning. Low concentrations of 2,4-D, 2,4,5-T and TD-692 show promise as date fruit thinning chemicals.

Salt tolerance. The reduction in growth rate of date seedlings irrigated with salt solutions varying widely in concentration was not proportional to increase in salt concentration of the substrate and a fourfold increase in salt concentration of the nutrient solution resulted in less than doubling the salt uptake by the date seedlings.

### 3. Miscellaneous sub-tropical fruits

Propagation. United States-sponsored P.L. 480 research in India on the use of chemicals to improve rooting of hard-to-root tree fruits showed that "ringing" (girdling) shoots several months before taking the cuttings benefited the rooting of mango cuttings from that shoot, especially when indole butyric acid (IBA) in lanolin was applied to the ringed area.

Flower induction. United States-sponsored research in India on the use of chemicals to increase fruit bud formation showed that napthaleneacetic acid (NAA) and maleic hyfrazide induced flowering in mango but both chemicals inhibited shoot growth. Ringing and short days, singly or in combination, did not overcome biennial bearing. Either Ringing or short days used singly were effective to increase flowering in a given season but in combination they were ineffective.

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TREE NUT BREEDING AND GENETICS, DISEASES  
VARIETY EVALUATION, CULTURE AND PHYSIOLOGY

Crops Research Division, ARS

Problem. Tree nut production in the United States is inadequate to meet the needs of the national consumption. Production of current varieties is not optimum and existing varieties are subject to diseases and frost damage to spring bloom. The nutritional requirements of nut trees are not completely known and the factors that induce biennial bearing are not understood. Diseases are often limiting factors and may even cause complete crop failure. Almonds are particularly subject to late frosts; later blooming varieties are feasible. Nut trees are known to have higher potassium requirements than the trees can absorb in heavy crop years but methods to increase absorption are not yet known. Current management research on tree spacing, dwarfing, rootstocks, and chemical fruit setters as well as more productive varieties have not yet achieved optimum production.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving breeders, plant pathologists, soil scientists, and horticulturists engaged in both basic studies and the application of known principles to the solution of growers' problems. Almond breeding research at Fresno, California, is cooperative with the California Experiment Station. Filbert breeding and cultural research at Corvallis, Oregon, is cooperative with the Oregon Experiment Station. Pecan variety evaluation, disease control, and cultural studies at Baton Rouge, Louisiana, and State College, Mississippi, are cooperative with the respective experiment stations. Disease control and orchard management at Albany, Georgia; disease control, orchard management and nutrition at Shreveport, Louisiana; variety evaluation, orchard management and breeding at Brownwood are at Federally operated stations. Research on walnut diseases and culture at Corvallis, Oregon, is cooperative with the Oregon Experiment Station. Breeding research and variety evaluation (chestnuts, filberts and hicans) is carried on at Beltsville, Maryland.

Grant or contract supported research is being done as follows: absorption and translocation of potassium by pecan at the Georgia Agricultural Experiment Station; absorption and translocation of zinc by pecan as well as the etiology of pecan shuck disease at the Texas Agricultural Experiment Station; control of pistillate flower formation in pecan at the Alabama Agricultural Experiment Station; the mode of inheritance of pecan scab resistance at the Mississippi Agricultural Experiment Station; the collection and evaluation of native pecan seedlings for horticultural characteristics at the Louisiana Agricultural Experiment Station; and the residue and breakdown products of chemical fungicides in pecan kernels at Stanford Research Institute, Menlo Park, California.

The Federal intramural scientific effort devoted to research in this area totals 12.5 scientist man-years. Of this number 2.5 is devoted to breeding and genetics; 3.0 to diseases; 1.0 to variety evaluation; and 6.0 to culture and physiology.

The Federal extramural scientific effort devoted to research in this area totals 1.8 scientist man-years. Of this number none is devoted to breeding and genetics; 1.2 to diseases; 0.2 to variety evaluation; and 0.4 to culture and physiology.

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 9.0 scientist man-years is devoted to this area of research.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAM

##### A. Breeding and genetics

1. Pecan. Numerous selections from the breeding program are definitely superior to some of the standard varieties in regards to bearing characteristics (precocity, regular bearing), early maturity, cracking and shelling characteristics, kernel keeping qualities. These selections are now being tested throughout the pecan belt for inherent disease resistance.
2. Walnut. Crop failure of Persian walnut is frequently caused by killing of pistillate flowers by late spring frosts. Black walnut is seldom damaged because it blossoms approximately one month later than most Persian walnut varieties. Inter-hybridization of Black and Persian walnuts could incorporate the late-flowering characteristic of black walnut in Persian walnut varieties thus eliminating the spring frost hazard in nut production.

Five first generation hybrid walnut trees produced by crossing a characteristically early-flowering Persian walnut with late-flowering native black walnut, flower later than the latest flowering black walnut varieties.

##### B. Diseases

###### 1. Pecan

Scab. Tests conducted at Albany, Cordele, and Fort Valley, Georgia, to determine the minimum dosage of fungicides dodine and DuTer required to control scab that 6 applications of dodine (65-W) at the rate of 5 lbs in 500 gallons of water and 2 lbs of DuTer (50%) in 500 gallons of water would control scab.

Shuck disease. Fewer diseased pecan shucks were found on the longer and stronger shoots and any factor of environment or culture that promotes shoot length and vigor reduces disease incidence.

## 2. Walnut

Bacterial blight. The Howe variety was again relatively free from blight; only 4.1 percent of the nuts on trees of this variety were infected whereas on adjoining trees of the Franquette variety, 26.4 percent of the nuts were diseased. This is the eighth consecutive year that the Howe has had significantly less blight than the Franquette variety.

Bordeaux mixture (4-2-100) was the most phytotoxic material tested in 1966. However, the damage was not serious enough to cause any significant injury. Copper hydroxide and copper carbamate at the concentration used did not cause any detectable foliage injury.

Under the conditions prevailing in 1966, copper hydroxide (Kocide 101) was more effective than any other spray material tested. Bordeaux mixture (4-2-100) was almost as good; copper carbamate gave the poorest results of any material used.

## C. Variety evaluation

Walnut. The proprietary varieties Hartley and Adams #10 as well as the California selection UC 49-46 were high quality ones that matured at least two weeks earlier than Franquette, the leading variety in Oregon.

## D. Culture and physiology

### 1. Pecan

Mineral nutrition. The use of nitrate of potash in low concentrations during leaf development stage continues to show promise of being a relatively inexpensive way to improve quality of pecan nuts.

Significant increase in yield was obtained with the Moore variety in the second year when the trees were sprayed with nitrate of potash at low concentrations during the leaf development stage. The kernel content of the nuts and the oil content of the kernels tended to be higher for the sprayed trees than for the unsprayed trees.

Grant-sponsored research in Texas showed the leaf zinc content with an accumulation of zinc from consecutive annual soil zinc applications greater than that from only one initial application. The broadcast-disked method of applying zinc to soil for pecan trees was more effective in providing zinc than deep placement methods.

Grant-sponsored research in Georgia showed the leaf, compared to stem and root tissue, the best indicator of the potassium status of the pecan plant. Potassium content in the leaf increased continually in response to K content in the nutrient solution; whereas K content in stems and roots increased only slightly and remained unchanged over a wide K content in the nutrient medium. Maximum differences in K leaf content induced by supply in nutrient

medium occur during July 1-August 1 in Georgia.

In young trees, foliar deficiency symptoms develop at a K leaf content below 0.8% and levels above 3.0% are toxic.

Bud dormancy. Grant-sponsored research in Alabama showed the number of hours at 35°F to break rest of dormant Stuart pecan buds was 300 hours in 1966 compared to more than three times that number in 1965. A heavy crop in 1965 appears to have caused a much increased chilling requirement.

Pruning. A significantly greater percentage of top grade nuts was harvested from Moore trees pruned to 25 feet in height than from unpruned 50-foot high trees.

Propagation. To propagate rootstocks by root cuttings it is necessary to develop both a shoot and a new root. Cuttings from young roots high in starch content were found to develop adventitious shoots most readily. Old, woody root sections can also develop shoots but are more susceptible to rot. Development of new roots from the cortex of a cutting is usually very slow. Application of a root-inducing hormone to the base of the cutting is effective in stimulating root formation but greatly retards shoot growth. The best type of cutting was found to be one having a lateral "feeder root" because such a small root readily puts out new ones without artificial stimulation.

When a pecan root cutting does not have a "feeder root", it is better to grow a plant from an adventitious shoot than from the entire cutting. This can be done by either of the following two methods: (a) Induce root formation while the shoot is still attached to the cutting by girdling and root-inducing hormone treatment; (b) Remove the shoot from the cutting when well developed and root by a standard procedure for softwood cuttings.

## 2. Almond

Rootstocks. Peach-almond seedlings which grew well for two years when used as rootstocks in high boron conditions have recently shown gumming symptoms, characteristic of boron toxicity.

## 3. Filbert

Spacing. The yield of 1872 pounds per acre for a 7-year-old orchard of closely planted trees (15X15 ft.) is outstanding. Such a high yield is more than double the yield of intermediately-spaced trees (20X20 ft.) and almost triple the yield of widely-spaced (25X25 ft.) trees.

Tree training. During the last 4 years, young single-trunked trees out-yielded multiple-trunked ones but the difference between yields became narrower. Multiple-trunked trees also complicate harvesting. Single-trunk tree training is currently recommended.

Mineral nutrition. Chlorine toxicity can result when heavy applications of the recommended potassium fertilizer KCl are made so late in spring that rainfall does not leach the chlorine below the feeder root level. Application of potassium chloride immediately after harvest is now recommended.

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## SWEET CORN BREEDING

## Crops Research Division, ARS

Problem. Although the seed industry is providing most of the hybrid seed corn in use today, there is still a need for some basic and applied work in genetics, physiology, and pathology.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program on the breeding of sweet corn for resistance to certain diseases and insects as well as to enhance the quality of the corn. For 1967 this amounted to 2.3 scientist man-years.

## PROGRAM OF STATE EXPERIMENT STATIONS

A total of 2.0 scientist man-years were devoted to sweet corn seeding in 1967.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

**Sweet Corn Breeding.** Earlier inbred lines and F<sub>1</sub> hybrids with earworm and *Helminthosporium* resistance, good quality and ear characteristics, and which are adapted to production in the Southeast were developed. Several selections from a composite of germ plasm consisting of three New Jersey composites and several of our own sources of earworm resistance have undergone sufficient inbreeding to permit testing them in hybrid combinations.

Studies on the use of endosperm mutant genes to improve sweet corn quality were continued. Twenty-five experimental hybrids possessing various combinations of the genes ae, du, su<sub>1</sub>, and wx were analyzed for carbohydrate contents at harvest and after 7 days of post harvest storage at 68°F. Genotypes ae wx, ae du wx, du su<sub>1</sub>, and du su<sub>1</sub> wx, showed higher sugar contents at harvest than normal (su<sub>1</sub>) sweet corn and approached that of 'Illinichief Supersweet' (sh<sub>2</sub>). They also had good sugar retention during the post harvest storage period. Most of the mutant types were rated sweeter than su<sub>1</sub> alone by taste test, but they were tough. It was apparent that further selection, and probably additional backcrosses, would be necessary to refine all the quality characteristics for an acceptable sweet corn hybrid.

A preliminary test was made on 8 different genotypes to determine what effect endosperm mutant genes have on shrinkage of the seed upon drying. Genotypes ae su<sub>1</sub> and du su<sub>1</sub> produced heavier and less shrunken kernels than su<sub>1</sub> or sh<sub>2</sub> alone and seedling vigor was superior to the standard lines. The triple mutant combinations generally produced lighter seed and weaker seedlings than single or double mutant types. Hopefully a combination of genes can be obtained that will improve the quality of the corn without any impairment of seed or plant performance.

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POTATO BREEDING AND GENETICS, DISEASES,  
CULTURE, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. The potato is grown in every State and is planted or harvested every month of the year. Yield and culinary and processing qualities vary greatly because of the extreme environmental differences among the many production areas. The rapid increase in potato processing--approximately 35% of the tablestock crop is now converted into over 50 processed products--has increased the demand for suitable varieties to resolve the many quality factors that have appeared in these new products. Knowledge of genetic control of enzymatic systems is needed for synthesizing new varieties adapted to processing. New methods of breeding, more inter-specific hybridization, and more resistance to specific diseases are needed to increase the yield and quality of the potato. Understanding the nature of disease and insect resistance and the methods for controlling disease agents is necessary to reduce crop losses and to decrease the need for chemical control.

## USDA AND COOPERATIVE PROGRAM

The Department has a long-time program for the improvement of the potato by breeding methods, disease control, and cultural practices. Breeding, selecting, and testing new varieties and seedlings for horticultural characters, storing, shipping, and culinary qualities and local adaptation are conducted cooperatively with the States at Presque Isle and Orono, Maine; Greeley and Center, Colorado; Aberdeen, Idaho; Baton Rouge, Louisiana; Riverton, New Jersey; Ithaca, New York; Prosser, Washington; College Station, Texas; Madison, Wisconsin; and Morgantown, West Virginia. In addition, new seedlings are evaluated at more than 25 other locations in cooperation with State personnel.

Production of true seed and the growing of seedling tubers in order to develop new varieties are done at Beltsville, Maryland; Aberdeen, Idaho; Baton Rouge, Louisiana; Riverton, New Jersey; Prosser, Washington; Ithaca, New York; and Madison, Wisconsin. In cooperation with the Rockefeller Institute at Mexico City, seedlings from Beltsville are evaluated for field resistance to severe late blight epidemics. The world collection of Solanum stocks of the Inter-Regional Potato Introduction Project (IR-1) is maintained at Sturgeon Bay, Wisconsin. Diploids of Solanum tuberosum (half the normal chromosome number) are produced and studied at Madison, Wisconsin. At Beltsville investigations of crossability among Solanum species and meiosis of species and species hybrids are being concluded.

In cooperation with the Entomology Research Division, a 3-year Federal Grant is currently in effect with Iowa State University at Ames, Iowa, to study the basic nature and significance of plant alkaloids in potato leafhopper-host relations involved in plant resistance.

Three 5-year PL 480 projects are currently in effect: (1) with the Polish Academy of Science, Cracow, Poland, for the study of environmental factors affecting quality of tubers used for seed; (2) with the Estacion de Mejora de la Patata, Vitoria, Spain, to develop techniques for eradicating, inactivating, or curing potato tubers from their tuber-borne viruses; and (3) with the Central Potato Research Institute, Simla, India, for the utilization of haploids in the breeding and genetics of potato. In informal cooperative arrangement between USDA and AID for potato improvement in Nigeria is being carried out.

The Federal program devoted to research in this area adds up to 15.2 scientist man-years divided as follows: 8.0 assigned to breeding and genetics, 6.0 to diseases, 1.0 to culture, and 0.2 to variety evaluation.

The scientific effort devoted to the Extramural Research Program totals 0.4 scientist man-years devoted to breeding and genetics.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 56.8 scientist man-years.

#### PROGRESS--USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

1. Potato Introductions. In cooperation with Plant Introduction Investigations of the New Crops Branch, 175 stocks were received in 1966 from 15 foreign countries. Seed samples of 144 introductions were sent to the National Seed Storage Laboratory, Fort Collins, Colorado. Shipments to 20 States and 17 countries included 1,267 seed and 455 tuber samples of germ plasm developed by the cooperative USDA-Wisconsin Genetics and Cytogenetics Project.

2. Potato Cytogenetics. In Wisconsin the use of haploids and diploid species in genetics and breeding was continued. To facilitate the utilization of diploid species, one cultivated and six wild diploid species were used to synthesize four intraspecific bulk populations and eight hybrid populations involving haploid-species hybrids. In the following generation, bulking of siblings and selection for tuberization will be practical to develop highly variable germ plasm pools useful to potato breeders. Vigor is severely reduced in  $S_2$  and  $S_3$  generations from original matings between diploid tuber-bearing Solanum species and tuberosum haploids. Studies of trisomic plants showed 17 of the 24 grown in 1966 produced flowers. Most trisomic plants will be female fertile, but some will be male fertile. In crossability studies of diploids grown at Beltsville, seed was obtained from 39 interspecific crosses among diploid species. None out of 15 ciploid hybrid crosses with S. verrucosum as the female parent was male sterile. Seed was obtained by backcrossing to the male parent in 8 of these progenies.

3. New Releases. Alaska Frostless was released cooperatively with the Alaska Experiment Station. Foliage of this release survives field temperatures of 27° F. It has good culinary characteristics. Its production of medium-sized white tubers is slightly less than those produced by Green Mountain variety.

4. Insect Resistance. In Ohio significant differences between seedlings were found for damage by fleabeetles (Epitrix cucumeris). Correlations of fleabeetle damage with hopperburn injury and leafhopper count were low and nonsignificant. Hopperburn injury by the leafhopper (Empoasca fabae) was highly correlated with yields in untreated plots. The size of the nymphal population on any one of the 14 seedlings tested does not necessarily indicate its resistance or susceptibility as might be measured by hopperburn injury or the untreated/treated yield ratio.

5. Nematode Resistance. Sixteen out of 24 advance selections were checked for resistance to golden nematode (Heterodera rostochiensis) in cooperation with the New York Station. Several resistant selections had early maturity, multiple resistance to several diseases, and yields and processing qualities suitable for commercial varieties. Several selections from family line B6377 were tested cooperatively with AID in Nigeria and proved to be highly resistant to the root knot nematode (Meloidogyne spp.). Resistance to late and early blight was also observed in this material.

6. Varieties for the South. In Louisiana three seedlings, TL7935, TL8134, and TL8197, show considerable promise as future varieties and are being increased in North Dakota and Nebraska for further evaluation.

7. Varieties for the West. In Colorado 234 selections were made from 25,000 seedlings grown for the first time in 1966, and 64 selections were made from advance seedlings. The two most promising seedlings from the yield and chipping tests were B5141-6 and B5042-2, which were low in reducing sugars regardless of storage treatment.

In Idaho, seven advance seedlings and six newer varieties were compared with Russet Burbank at two locations for yield, specific gravity, resistance to Verticillium wilt, and for french-fry color. Seedling W44-3A was as good or better than Russet Burbank in all categories mentioned.

In Washington 91 out of 50,000 seedlings grown in 1966 were selected for increase and evaluation. Seedling 48-1 is being increased as a commercial sort because its yielding ability and specific gravity are equal to those of Kennebec. It also possesses resistance to leafroll and Verticillium wilt, and has less internal coloration than Russet Burbank. Total yield of 835 cwt. per acre for seedling 48-1 compares well with 671 for Russet Burbank.

8. Outstanding Seedlings. Seedling B5141-6 is being increased for release because of its high solids, chipping qualities, and low sugar content in many production areas. B5036-40 will be released soon. It is widely

adapted, resistant to the golden nematode, viruses X and A, *Verticillium* wilt, and has low translucency in frozen potato products. B5066-3 will also be released because it has early maturity, yielding ability, and resistance to scab, *Verticillium* wilt, and virus A. This is a table variety well adapted to heat-processed products.

9. Quality Evaluation of Seedlings and Varieties. One hundred and nineteen seedlings and varieties and 150 advance selections were compared for yielding ability, U.S. No. 1 grade percentages, specific gravity, and chipping quality. Yields varied from 484 cwt. of U.S. No. 1 tubers per acre to 168 cwt. Specific gravity readings ranged from 1.121 to 1.068. Chip color varied from 2.5 (very light) to 9.8 (very dark). From the 150 advance selections 32 will be increased in 1967 because of their yielding ability and/or tuber qualities. Fourteen of the 150 rated 4.0 or lower for chip color after storage at 40° F. for 4 months and reconditioning for 2 weeks before frying and 12 of these had specific gravities ranging from 1.103 to 1.121. Seedling B6024-3 is a good example of a russet type, with medium to early maturity, that had excellent tuber appearance, 3.0 for chip color, 281 cwt. per acre for yield, and 1.111 for specific gravity.

In cooperation with Campbell Soup Company, 24 varieties were grown in replicated plots at five locations: New Jersey, Ohio, Wisconsin, Pennsylvania, and Maine. This material plus 269 additional selections grown in Maine were evaluated for yield, specific gravity, french frying, sloughing, and translucency before and after storage at various temperatures. Seedling B5036-40 was rated acceptable for low translucency at all locations. Additional trials at 5 locations in Texas showed selections B5090-11, B5036-40, B5141-6, B5066-3, and B5088-7 were outstanding for yield and appearance. Seedling B5141-6 had the highest specific gravity rating at all locations and compared favorably with the others in yielding ability.

10. Grant - Iowa. In cooperation with Iowa State University and the Division of Entomology for the study of potato leafhopper-host relations, differentiating morphological features between males and females were found. The study of the anatomical structure and functioning of the leafhopper ovipositor in placement of eggs in host-plant tissue are near completion.

#### B. Diseases.

1. Potato Spindle Tuber Virus. Seed Transmission. The seed from 5 symptomless hosts, infected with potato spindle tuber virus, was germinated and plant tissue indexed on Rutgers tomato to see whether PSTV could be transmitted through the seed of symptomless hosts. No transmission of the virus through these seeds was found.

2. Potato Viricides. Five chemicals, systemic in action, and supposedly capable of inhibiting virus transmission and expression, were evaluated for control of viruses A, X, Y, X + Y (rugose mosaic), and potato spindle tuber. No control was obtained with these chemicals.

3. Local-lesion Hosts. Several genera and species of plants in the Scrophulariaceae (figwort) family, not commonly used as indicator plants for viruses, were checked to find local-lesion hosts for virus S, potato spindle tuber virus, and the unmottled curly dwarf strains of PSTV. No local-lesion hosts were found among genera tested.

4. Multiple Disease Resistance. In Maine, 48 advance selections were tested for resistance to 10 potato diseases: ring rot, scab, Verticillium wilt, leafroll, net necrosis, stem-end browning, viruses X, A, and Y, and late blight. Seedling B5415-6 showed resistance to 6 of these diseases. B5458-6, a medium maturing russet type, had excellent chipping and yielding ability combined with resistance to scab, Verticillium wilt, leafroll, net necrosis, stem-end browning, and virus X and A.

5. Multigenic Field Resistance to Late Blight. In cooperation with Dr. M. E. Gallegly of West Virginia University and Dr. J. S. Niederhauser of the Rockefeller Foundation in Mexico, tests for field resistance were conducted in Maine, West Virginia, and Mexico. Over 15,000 plants from the seed of 40 family lines were screened with race 1,2,3,4 of Phytophthora infestans. Two early maturing seedlings, B5090-11 and B5422-9, showed a high degree of multigenic resistance to late blight and over 40 other seedlings having late maturity were rated as very resistant.

6. PL 480, Spain. At Vitoria, Spain, the work to free potato tubers of viruses continues. Presently, 2 tubers of Irish Cobbler, supposedly free of virus X have been returned to us for varietal identification and verification of absence of virus X.

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SWEETPOTATO BREEDING, GENETICS,  
VARIETAL EVALUATION, AND DISEASES

Crops Research Division, ARS

Problem. The total production and per capita consumption of sweetpotatoes, as well as the acreages of the crop grown, have been declining more or less continuously for many years. They have now reached the lowest levels in over a half century. Costs of sweetpotatoes to the consumer remain high and need to be reduced if use of the crop is to be increased. Further reductions in the high labor requirements involved in production, harvesting and handling must be achieved through maximum use of mechanization. Both better adapted equipment, and new high quality, disease resistant, productive varieties suited to mechanized methods need to be developed. Means must be found to reduce losses caused by diseases. There is particularly urgent need to find means of combating serious virus diseases such as russet crack which is currently making growing of some varieties impossible in certain production areas.

## USDA AND COOPERATIVE PROGRAM

The breeding program has been continued at Beltsville in the search for better disease-resistant types suited to fresh market and processing requirements. Characteristics considered in the program are root shape and uniformity; appearance; size; set; skin and flesh colors; overall yielding capacity and quality properties, storability, propagative characteristics, general plant vigor, and growth habits; adaptability to mechanized culture and handling procedures; and resistance to diseases and pests. Pathological studies are conducted and techniques developed for eliminating virus infections. Investigators in 20 States cooperate in the sweetpotato improvement program. Coordination of the overall cooperative improvement effort is handled at Beltsville, Md. A program to develop better sweetpotato breeding parent lines is conducted at Tifton, Georgia, by Federal workers in cooperation with the Georgia Coastal Plain Experiment Station. The program includes quantitative and qualitative genetic studies and also cytogenetic studies of other Ipomoea species.

The Federal effort devoted to research in this area totals 3.0 scientist man-years annually. Of this total, 2.0 are devoted to breeding and genetics and 1.0 to diseases.

## PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 26.0 scientist man years.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Breeding, Genetics, and Varietal Evaluation

1. Breeding and Cytogenetic Studies. The collection of Ipomoea species at Tifton, Ga., was expanded slightly and a few new chromosome numbers were determined this year. Species crosses were grown and hybrid origins verified. Interesting hybrids have been obtained with leads suggesting the possible origin of sweetpotatoes. In continuation of studies with Genome A Ipomoea species plants in which chromosome complements had been built up by colchicine and other techniques, stocks having 30, 45, 60, and 90 chromosomes were selfed and intercrossed this year. Seeds obtained from 45-chromosome and 90-chromosome plants appeared normal but were hollow and non-viable.

Plans are in progress for future maintenance of sweetpotato germ plasm by multiple-location storage of seed produced by random-breeding populations possessing wide, and gradually expanded, gene-source bases. Seed thus produced and stored could be protected against loss.

2. Applied Breeding. In 1965-66, 18 parent clones were used in the breeding program at Beltsville. After screening for desirable flesh colors, and preliminary evaluations for horticultural characteristics, edible quality, enzymatic darkening potential, and storage properties, 23 selections have been retained for additional testing, out of 6,078 new seedlings produced in 1966. Further evaluation, in 1966, of the 45 new seedlings saved in 1965, resulted in selection of 6 for further comparative yield and other tests. Starting in the fall of 1966 the breeding program formerly conducted at the Maryland Experiment Station was consolidated with that of USDA and the Beltsville work was expanded to utilize 30 selected parent stocks (15 USDA and 15 others previously used at Maryland).

3. Testing of Advanced Selections. B7557, a wilt-resistant, high-quality selection, compared favorably with the high-yielding varieties Centennial and Nemagold in No. 1 grade and total yields in replicated field trials at Beltsville. B7537 was a heavy producer of canner stock. In regional trials, conducted in cooperation with the Maryland, and 17 other State experiment stations, both Gem (NC-188) and NC-212 were high-yielding but both showed excessive susceptibility to cracking damage. C-56-35 produced well and looked promising in these tests.

4. Enzymatic Discoloration in Selections. Of 47, 1966 seedling selections, tested for extent of enzymatic darkening, 12 gave significantly lower flesh discoloration indexes than the varieties Goldrush, Nemagold, and Porto Rico. Six of the 12 low-index selections are among those retained for further observation and evaluation in 1967.

5. Resistance to Insects in Sweetpotato. Fourteen sweetpotato lines were analyzed chromatographically to isolate chemicals to which larvae of cucumber beetle and wireworm would be either attracted or repelled. Results were

confused because of the large number of spots on the chromatograms. However, differences between lines were noted, and, with refinement of techniques, it is hoped more satisfactory results may be obtained.

#### B. Diseases

1. Black Rot. Six of 18 selections, tested for reaction to 3 mycelial strains of black rot using the puncture-inoculation technique, showed practical levels of resistance. 296116, an introduction from the Philippines, was highly resistant. 304088 introduced from Central America, NC-212, and the Beltsville selections 7546, 7622, and 7643, were the other resistant lots.
2. Viruses. Application of the 100° F. heat treatment to "mother" plants, for control of internal cork, chlorotic leafspot, and yellow dwarf viruses, for periods of two months or longer, rendered them incapable of producing fleshy roots either in the 100° chambers or when removed to the regular greenhouse. However, plants grown from vine cuttings taken from the heat treated "mother" plants developed fleshy storage roots after 4 months in the greenhouse. Development of such storage roots is essential for application of the root-lesion criterion for identifying the russet crack virus in those selections which do not produce foliage lesions distinctive of the disease.

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#### Breeding, Genetics, and Variety Evaluation

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ONION, CARROT, AND OTHER ROOT AND BULB  
CROP BREEDING, GENETICS, AND DISEASES

Crops Research Division, ARS

Problem: The production of carrots, onions and related crops is stabilized in highly specialized growing areas, most varieties being limited to rather narrow ranges of adaptation and use. Susceptibility to diseases and insect attack further limit the general suitability of some varieties. Genetic control of male sterility for use in hybrid carrot-seed production has not been mastered, and there are other serious seed production problems in both onions and carrots. Continued research in the areas of pathology, physiology, genetics, cytology, and male sterility is needed to enrich the many public and private breeding programs on these crops throughout the U.S.

## USDA AND COOPERATIVE PROGRAM

The primary objectives have been to develop improved breeding lines, varieties, and hybrids of onions and carrots that are disease- and insect-resistant, high-yielding, high-quality, genetically marked for purity maintenance, and suitable for special purposes. Federal personnel located at Beltsville, Maryland, and Greeley, Colorado, cooperate with State Experiment Stations, seed and food-processing companies in the supply, evaluation or increase of breeding lines. The major research at Beltsville has been: Control of diseases and insects by breeding, utilizing both cultivated and related wild species of Allium and Daucus as germ plasm sources; cytoplasmic male sterility; quantitative inheritance; and cytogenetics. Support personnel worked with Vegetable Seed Investigations at Fort Collins, Colorado, on the problem of onion-seed yield failures in the West. In cooperative resistance work, onion lines have been screened for resistance to pink root by Texas and Oregon Agricultural Experiment Stations, purple blotch by Nebraska Agricultural Experiment Station, downy mildew by Keystone Seeds, California, and thrips by Ohio Agricultural Experiment Station and Entomology Research Division, Beltsville, Maryland.

The domestic program is supplemented by four PL 480 projects: onion downy mildew and carrot-root greening, Poland; development of carotene bodies in carrot and nature of cytoplasmic male sterility in plants, Israel.

The Federal scientific effort totaled 2.0 scientist man-years assigned to breeding and genetics.

## PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 22.0 scientist man years.

## PROGRESS -- USDA COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Linkage testers in onions. An additional 120 plants were examined for trisomic chromosome ( $2n + 1$ ) chromosome complements. From triploid x diploid and reciprocal crosses, 29% of the functional eggs produced by  $3n$  plants were ( $n + 1$ ) whereas only 7% of functional pollen grains had this chromosome constitution.
2. Onion variegation. In a line with variegated foliage, a strong within-plant correlation between amount of variegation of "mother" plant and proportion of albino and variegated offspring provided evidence of maternal inheritance of a plastid mutation.
3. Onion thrips. In greenhouse tests conducted by Entomology Research Division, onion line B 3343, which has field resistance in Ohio tests, was nearly as seriously damaged by thrips as the fully susceptible check. PI 211902, while not free of thrips, nevertheless showed considerable promise as a source of resistance.
4. Release of brown-seeded onion lines. Male-sterile and maintainer lines of two inbreds homozygous for mutant brown seed were distributed to breeders with suggestions for their use in a novel method of hybrid seed production.
5. Male sterility.
  - a. For a quantitative approach to carrot male sterility, 140 plants were scored numerically at Beltsville as to percent pollen abortion rather than as simply sterile or fertile on the basis of subjective appearance of anthers. Nevertheless the population fell into a bimodal distribution, the greatest mode being at 0% good pollen and a second one at about 85%.
  - b. In an attempt to create cytoplasmic male sterility by genome transfer into foreign cytoplasm, pollinations of radish by cabbage were made at Beltsville, cooperative with the U.S. Vegetable Breeding Laboratory at Charleston, S.C. A number of pods have set seed.
  - c. Following successful transmission in Petunia, several attempts have been made to transmit cytoplasmic male sterility in pepper by grafting, and in onion and carrot by dodder. These attempts have been unsuccessful so far. (PL 480 grant, Israel).

## 6. Carrot pigmentation

- a. Root greening of carrots occurs at a relatively early stage of growth, and in "susceptible" varieties, it will increase within two weeks after partially uncovering the roots in the field. The amount of greening in a particular callus-tissue culture is not correlated with previous environmentally induced greening of the source root, but depends rather on its genetic predisposition to greening. (PL 480 grant, Poland).
- b. From electron micrographs of sections through developing and mature carotene bodies in carrot roots, carotene bodies are interpreted as originating in proplastids. The bodies at maturity consist of an outer multi-layered lipoproteinic membrane system with or without carotene, and an inner core containing most of the, probably crystalline, carotene. (PL 480 grant, Israel).

7. Regulating carrot-plant height. The growth regulator B-Nine (n-dimethyl amino succinamic acid) was effective in shortening carrot flower stalks to proportions more suitable for experimental crossing manipulations in the greenhouse. However, the concentrations applied were detrimental both to pollen production and seed set.

8. Onion seed production. Yields of hybrid onion seeds have been so low and variable that continuation of hybrid seed production is threatened. Causes of low yields are unknown. Workers at Fort Collins, Colorado, collected developing umbels from commercial fields in southwestern Idaho. By separating florets into developmental classes, losses due to "abnormal" florets were found to be 20 to 48% higher in hybrids than in an open-pollinated variety. An additional loss, 6 to 32% higher in hybrids, resulted from failure of seed development within "normal" ovaries.

## B. Diseases

1. Onion mildew. In onion downy mildew epidemiology studies in Poland (PL 480 grant) sporulation usually occurred at night or on rainy days. Plant infection occurred the following night after daytime spread of the spores. Temperatures 20° C. or above for five hours greatly delayed spore germination.

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PEA AND BEAN BREEDING, GENETICS,  
DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Newly developed varieties of beans and peas must be widely adapted, productive, of high quality, and suitable for mechanical harvesting. Since diseases are the major obstacle to increased production, the development of multiple-resistant varieties is being given top priority. Biological control of pests through breeding and other means are preferred when feasible to chemical methods. Efforts to develop stem anthracnose and nematode resistance in lima beans must continue. With the acreage increase of southern peas in the South, additional information is needed on disease control of this crop and also for dry peas and lentils in the West. Because there is need for increased production of pulse crops in developing countries to help reduce nutritional shortages, particularly protein, information is required on insect and disease control, varietal improvement, and better crop management practices.

## USDA AND COOPERATIVE PROGRAM

The research is cooperative with the State Agricultural Experiment Stations in Georgia, Michigan, Oregon, and Washington. At Beltsville, Maryland, studies on breeding techniques and on the inheritance of resistance to certain diseases of snap beans and lima beans are conducted, and aid in the evaluation of breeding materials at the several field locations is provided.

At Prosser, Washington, breeding studies are conducted on dry beans for the West and on snap beans for the entire country. Major objectives are to develop resistance to several mosaic diseases, curly top, and Fusarium root rot. Inheritance of resistance to curly top in both dry and snap beans is also being studied. Breeding of disease-resistant peas is conducted at Prosser and on southern peas at Tifton, Georgia. The objective on peas is the development of disease-resistant breeding stocks for variety development by commercial breeders of seed and by processing companies. At Pullman, Washington, the development of superior lentil and dry pea varieties is conducted.

At East Lansing, Michigan, breeding and selection of disease-resistant pea bean, Red Kidney, and Cranberry types chiefly for Michigan and New York are conducted.

At Charleston, South Carolina, disease-resistant snap beans for market and processing are bred for adaptability to the Southeast.

At Beltsville, Maryland, pathologic studies on virus, fungus, and bacterial diseases and development of control measures are conducted on snap, dry, and lima beans and peas. Similar studies on dry beans are conducted at East Lansing, Michigan, and on virus diseases of peas in the Northwest at Corvallis, Oregon. Work, mainly of fungus diseases of peas, is conducted at Prosser, Washington, and diseases of southern peas at Tifton, Georgia. The relationship of nematodes to root rot infection of beans is also investigated at Prosser, Washington. Studies on diseases of dry peas and lentils are made at Pullman, Washington.

In Iran and India, work is in progress on the USDA/AID Regional Pulse Improvement Project. The objectives of this project are to increase production and quality of pulse crops for all areas of the Near and Far East through research on varietal improvement, soil and crop-management practices, and insect and disease control through breeding, chemical, and biological methods. A cooperative project with AID on disease and insect control of dry beans through breeding is conducted in El Salvador, Central America.

The Federal scientific effort in the U.S. devoted to research in this area totals 11 scientist man-years. Of this number 4.5 are devoted to breeding and genetics, 6.0 to disease, and 0.5 to variety evaluation. The scientific effort assigned to the USDA/AID Pulse Project totals 6.0 scientist man-years divided as follows: breeding and genetics, 3.0; diseases, 2.0; and variety evaluation, 1.0.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 49.0 scientist man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

###### 1. Dry Beans

a. Disease resistance. In Washington, Bigbend and Coulee, varieties of Red Mexican released in 1966, brought favorable response from the bean industry. Bigbend is expected to occupy most of the Red Mexican acreage in the Columbia Basin this year. Two high-yielding, curly top- and mosaic-resistant Red Kidney lines were selected for increase and further evaluation in commercial plantings in 1967. Both may be released in 1968. Progress continues in the development of Red Mexican, Pinto, Pink, and white

beans of good quality and resistant to root rot and the important viruses. Twenty advanced lines were increased for evaluation in 1967. In Michigan, Seafarer (pea bean type), a replacement for Seaway and superior to it in yield and anthracnose resistance, was released early in 1967. Manitou, a Light Red Kidney type resistant to 3 races of anthracnose, was also released in 1967. Progress is being made in the development of Fusarium root rot resistance combined with anthracnose and virus resistance in pea bean types.

b. Disease-resistant beans for El Salvador. Progress continues in the production of black- and red-seeded types resistant to viruses, rust, and angular leaf spot (in cooperation with the U.S. Agency for International Development). Progress is also being made in the development of tolerance to web blight (Pellicularia filamentosa) and yellow mottle virus (whitefly transmitted). About 1800 pounds of a new, semi-vine, black-seeded variety resistant to common bean mosaic and tolerant to rust and web blight has been increased for widespread testing and later release to growers. It produced 1760 pounds of seed per acre compared with an average of 600 pounds per acre of the commonly planted types. Two other types, similar but viny, are also being increased for use in mature corn fields where beans are supported by old corn stalks. Another heavy yielding, viny, black-seeded type resistant to mosaic and rust is also being multiplied for grower release.

## 2. Snap Beans

a. Disease resistance. Yakima, the curly top-resistant snap bean released in 1965, has been well received by truck gardeners in the Columbia Basin.

More than 100 lines from the F<sub>1</sub> to F<sub>7</sub> generations were screened for multiple resistance to curly top, common (CBMV) and bean yellow (BYMV) mosaic viruses, Fusarium root rot, and for horticultural quality in 1966. About 40 advanced generation lines resistant to curly top and common mosaic were tested for quality and the 10 outstanding ones, together with 30 others, will be included in the 1967 preliminary yield trials. The superior lines will be canned and increased for commercial processing trials in 1968.

An F<sub>6</sub> white-seeded bush (GN 31 x D 9) having high tolerance to BYMV was selected in 1966. This virus could be a threat to bean growers in the Columbia Basin, especially in late plantings. This line is also resistant to curly top and CBMV. Canning and yield tests will be conducted in 1967.

Several F<sub>1</sub> hybrids (curly top-resistant bush x Blue Lake pole) were irradiated in an attempt to break a close linkage governing bush and pod quality and segregants from these hybrids will be screened for desirable virus-resistant bush types in 1967.

b. Nematode resistance. Selections for bush type, flavor, and pod characteristics, made within lines resistant to the root knot nematode (Meloidogyne incognita acrita), were backcrossed to high quality lines. The F<sub>3</sub> progeny are currently being increased for fall evaluation. The nature and inheritance of the resistance, obtained from P.I. 165426, is being studied. Resistance is superior to that found in Alabama #1 and may be conditioned by an entirely different genetic system.

An F<sub>1</sub> interspecific hybrid, Phaseolus vulgaris x P. polyanthus, has been obtained and will be used in a backcross program with P. vulgaris.

c. Breeding lines for the Southeast. The extreme dwarf mutant, previously described as a simple recessive, has been verified. A backcross of the hybrid (dwarf x normal) to the recessive segregated in a 1:1 ratio. A new dwarf mutant with white seed has been found.

Development of pure lines with ruptured seed coat phenotypes B, C, and D is near completion. These pure lines will be crossed with the normal type to determine the nature of inheritance.

Experiments recently completed ranging over a two-year period with 49 varieties show that variations in external pod structure account for approximately 68 percent of the total weight loss over a five and one-half day storage period. Internal structure measurements accounted for approximately 20 percent of the total weight loss. Approximately 12 percent of the weight loss has not yet been accounted for. Most of this loss could be from the stem-end and suture areas which were not studied. Knowing the structural areas associated with weight loss, improved breeding methods can be developed which should lead to longer storage life of harvested snap beans.

d. Variety release. A white-seeded variety named Bonus was released for processing, home garden, and fresh-market use. The new variety grows equally well in southern areas during spring and fall and in northern areas during the summer months. The plants produce a strong vigorous root system, a characteristic usually associated with good top growth and high yields.

### 3. Lima Beans

a. Disease resistance. Green Fordhook 861, resistant to downy mildew, was released in 1966. This variety continues to show promise in commercial plantings in New Jersey. There should be approximately 125,000 pounds of seed produced in 1967 for use by processors in 1968.

Baby limas G 1 and G 2, resistant to the 2 strains of downy mildew, outperformed Thaxter in 1966 commercial plantings. Frozen samples were identical to Thaxter. Additional hybrids having darker green seedcoats and

cotyledons than G 1 and G 2 are being tested. Jackson Wonder types resistant to the 2 strains of downy mildew continued to show promise in the 1966 trials by being more productive than Jackson Wonder.

b. Nematode resistance.  $F_3$  lines from the cross Nemagreen x Jackson Wonder were evaluated for resistance to root knot nematodes; resistant  $F_4$  plants were backcrossed to Jackson Wonder and selections for nematode resistance made in the resulting  $F_2$  population. A crossbreeding population will be established, using a genetic male sterile line to increase cross-pollination. This should allow effective selection over a greater number of generations than is possible with self pollination.

c. Air pollution damage. Air pollution injury causing a red necrotic spotting on the leaves and pods of breeding lines and varieties of lima bean followed by a leaf defoliation and pod drop was noted in the 1965 and 1966 field trials in New Jersey and Delaware.

#### 4. English Peas

Disease resistance. In greenhouse tests, 65 lines were screened for root rot resistance and only one P.I. line (#140165) showed promise as breeding material.

#### 5. Dry Peas and Lentils

Thirteen superior breeding lines of yellow-seeded dry peas and 17 superior Alaska types were chosen for uniform yield trials in 1967. Three outstanding lines of lentils were chosen for superior yield, seed size, acceptable color, and vine habit for 1967 tests. Also, about 500 single-plant selections were made from these 3 lines which will be increased to produce breeders' seed for release in 1968. Selections for improved seed size, color, yield, vigor, plant height, and resistance to lodging were made from crosses involving 7 different parents.

#### 6. Legumes for the Near East

In Iran more than 9,000 germplasm strains of various pulses were screened in observation nurseries and about 475 promising strains were tested for yield in replicated trials. Seed of the superior varieties of beans, chickpeas, cowpeas, and mung beans are being increased and after further testing in 1967, recommendations will be made to the Iranian Ministry of Agriculture for release and distribution of the superior varieties. Studies on date of planting, spacing, fertilizer, and irrigation practices show that a considerable potential exists for improved yields.

In India, a total of 10,000 germplasm collections of chickpeas, mung beans, urd beans, pigeon peas, cowpeas, and Lathyrus sativus were screened at 3 locations for outstanding types. The All India Coordinated Varietal Trials

for the testing of varieties of pigeon peas, mung beans, urd beans, and chickpeas developed and released by the several States in India were started. Investigations on the neurotoxic factor that causes paralysis in humans who eat Lathyrus sativus are in progress.

B. Diseases

1. Beans and Lima Beans

a. Bean viruses. Work was completed on the Mexican strain of BCMV and the manuscript submitted for publication. Cooperative work on the western strain of peanut stunt virus (PSV-W) (previously assumed to be a strain of cucumber mosaic virus) is completed and will soon be submitted for publication. More than 50 bean varieties have been infected with the type PSV and thus far no resistant variety has been found. Ten lima bean and 12 cowpea varieties were also infected; also many other legume species.

Eight distinct viruses have been found to be seedborne in red clover in the Northwest. Five of these, i.e. clover yellow mosaic virus, white clover mosaic virus, tomato and tobacco ringspot viruses, and pea mosaic virus are strains of known viruses. Of the other 3, one is serologically distinct from bean yellow mosaic virus, another is serologically related to pea streak virus, and the third is distinctly different from any previously reported legume virus. New buffering and purification procedures have made possible the production of a highly concentrated, highly infectious, partially purified preparation of BYMV. The pea aphid was found to be an efficient vector of the pea streak virus.

b. Bacterial diseases. Further studies on the application of copper compounds for the control of halo and common bacterial blights in Michigan resulted in a decrease in disease development and spread. Aerial application of the materials gave better control than ground application.

Soil assays for the presence of the halo blight organism in naturally infected field soil were positive after 6 weeks storage, but negative after the second 6-week interval. Serological and pathogenicity tests with the halo blight, pea blight, and brown blight organisms indicate that the halo blight organism will not infect peas as reported earlier by another investigator. A yellow bacterium causing chlorotic water-soaked angular leaf spots and unlike other bean bacterial organisms in culture was isolated from beans. In mixed cultures, this organism parasitized cells of Pseudomonas phaseolicola and P. fluorescens. This organism is being identified and its parasitic action on other Pseudomonads is being studied.

c. Fungus diseases. Preliminary results indicated that reduction of Pythium wilt was obtained by treating seeds with Chloroneb at the rate of 6 ounces per 100 pounds of seed. Fertilization with  $\text{NH}_4\text{NO}_3$  had no effect on root

rot. Ecological studies showed that beans were predisposed to root rot during low soil temperatures during seed imbibition of water and when the soil was temporarily saturated with water during seedling development. Collections of soil from bean roots in over 40 fields with different cropping histories all contained parasitic nematodes of 4 genera. Only one, Pratylenchus sp., increased root rot when added to soil infested with Fusarium solani f. phaseoli. A quantitative method for isolating Pythium sp. from soil was developed using autoclaved sweet corn seed. Due to the extreme variability of infection and the low incidence of bean rust in the eastern U.S., the breeding program for rust resistance has been terminated. In Michigan, a soil treatment program to control root rot using PCNB, Chloro Nitro Propane, and Chloroneb immediately prior to planting failed to decrease root rot development significantly. Foliar sprays of PCNB and Botran (1-1/4#/A) gave significantly better protection than Ferbam (3#/A)<sup>t</sup> lime.

## 2. English Peas

From frequency of isolation the primary pathogens involved in the pea root rot complex in Washington were Fusarium solani f. pisi and Pythium ultimum. Less numerous were Thielaviopsis basicola, Rhizoctonia solani, and F. oxysporum f. pisi race 2. Aphanomyces euteiches was seldom isolated. Interaction studies demonstrated that P. ultimum combined with F. solani f. pisi caused more severe root rot on Prince of Wales peas than when either pathogen was present alone or in combination with the near wilt fungus.

## 3. Dry Peas

Field surveys showed that approximately 17 percent of all dry peas grown in Idaho and Washington were infected with Fusarium root rot. Other diseases noted were Ascochyta pod spot, powdery and downy mildews, Rhizoctonia and Aphanomyces root rots, and white mold. Histological studies revealed the bacterium, reported in peas in previous years, was present in high concentrations in infected tissues. This organism was found to infect beans systemically. Field evaluations of 10 chemical seed treatments demonstrated their effect on increasing yields. Captan and Panogen were the most effective. Dieldrin and a nematocide were also effective.

## 4. Lentils

From field surveys and laboratory studies, the following organisms were isolated: Alternaria tenuis, Aphanomyces euteiches, Ascochyta pisi, Botrytis cinerea, Erysiphe polygoni, Sclerotinia sclerotiorum, Stemphylium botryosum, and Verticillium albo-atrum. The following chemicals used as seed treatments were effective in increasing yields: Methylmercury Dicyandiamide, PCNB, TCNA, Methylmercury Nitrile, various ethyl mercury salts, and Captan. A nematocide and the insecticides Dieldrin and Di Syston were also effective.

## 5. Pulse Crops in the Near East

The work consisted mainly of disease surveys and identification of the causal agents. In Iran, broad beans and lentils suffered more from diseases than the other pulse crops. Virus diseases were widespread in beans, broad beans, chickpeas, cowpeas, and mung beans. The viruses affecting these crops were identified as those of alfalfa mosaic (chickpea, cowpea, and lentil), common bean mosaic (bean), bean yellow mosaic (broad bean, chickpea, and lentil), and cucumber mosaic (broad bean). Several unknown viruses were found on bean, chickpea, cowpea, and mung bean. Root rot diseases were important on beans, chickpeas, and lentils. The following organisms causing these diseases were: Rhizoctonia solani, Macrophomina phaseoli, Fusarium solani f. phaseoli, and Pythium sp. Chocolate spot (Botrytis fabae) and broad bean rust (Uromyces fabae) were of importance on broad beans in the wetter areas. The former disease was responsible for most of the crop damage.

In India viruses appear to be more important disease agents in limiting pulse production than are bacteria and fungi. An unidentified yellow mosaic was found infecting pigeon pea, mung bean, and urd bean. No variety of mung or urd bean was free from the disease. The sterility virus of pigeon pea, which is mite transmitted, is potentially a serious disease. Fusarium wilts of pigeonpea, chickpea, and lentil are important and often cause considerable crop loss. Varieties of pigeon pea resistant in one area are often susceptible in another, indicating that races of the organism exist. Common bacterial blight (Xanthomonas phaseoli) often causes serious damage to mung beans and urd beans. Rust and powdery mildew of English peas were also observed. The organism Operculatella padwickii has been isolated from a high percentage of wilted chickpea plants.

## C. Variety Evaluation and Physiology

Fertilizing peas with a combination of K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> slightly reduced the protein content of dry pea seeds. Analysis of bean and lentil seed for total protein showed a high correlation between Kjedahl values and those obtained with the Udy method. Studies on protein content of more than 500 lots of dry beans demonstrated that varieties or types varied from 19 to 27 percent total protein. Very few varieties were found at either extreme, the majority being in the range of 21 to 24 percent protein. High quality seed contained less protein than low quality seed. Seed moisture showed little effect on percent protein. In general, more protein was found in seed of snap bean varieties than in those of dry bean types, black-seeded contained more than white-seeded types, and wrinkled peas more than smooth-seeded varieties.

Irrigation studies on snap beans indicate that yield, maturity, and pod sieve size distribution are very responsive to water stress or excess. Spacing studies with lentils showed that when the distance between plants

was decreased from 4 inches to 2 inches to one inch, seed yield increased and the number of pods per plant decreased, but the number of seeds per pod and the number of pods per peduncle was unaffected. At Prosser, Washington, a small plot thresher which allows greater recoverability, higher germination, and reduced seed injury was developed.

Spectrophotometric data and Rf values have been obtained for 14 phenolic compounds eluted from chromatograms of seedling snap bean leaves. Free aglycones were not found, and the only sugar present was glucose. These data indicate that the compounds are flavonol glycosides. One spot present in all varieties tested was identified as a quercetin glycoside. Another spot present in bush types and absent from pole types is a kaempferol glucoside. The absence of this particular spot in pole type beans and its presence in bush types could be used advantageously to determine seedling types in segregating populations.

Chromatographic analyses for flavonoids contributing to pod flavor have been continued. Varietal differences have been found, but chromatographic patterns seem to have little relationship to flavor as determined by taste tests. Flavonoids or other phenolics perhaps do not affect flavors. Other classes of chemicals, such as amino acids and essential oils, are being investigated.

Temperature sensitivity and development of bean seeds. Earlier work at Fort Collins, Colorado, had shown that the imbibition period of bean germination is especially sensitive to low temperature injury. In the case of lima beans, allowing either excised embryonic axes or whole seeds to take up water vapor until the seed moisture is about 30% eliminates temperature sensitivity. Preliminary evidence with snap beans suggests that raising the seed moisture may also increase early seedling growth. Studies of the development of lima bean seed have shown that the ability of excised embryonic axes to survive desiccation appears just prior to seed maturity. Experiments, done cooperatively with PL 480 work in Israel, have related the ability of embryonic axes to withstand drying to other features of seed development.

Submicroscopic cellular changes in developing bean seeds. In a PL 480 project at Jerusalem, Israel, scientists found that cells contain many ribosomes combined into "polysomes" until the seeds approach maturity; at that time the ribosomes appear as single units. This change in cell structure appears closely related in time to the developing ability of the cells to withstand desiccation.

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TOMATO, PEPPER, AND RELATED CROP BREEDING,  
GENETICS, DISEASES, AND CULTURE

Crops Research Division, ARS

Problem. The rapid progress toward total mechanization of the tomato harvest has forced drastic changes in tomato-improvement programs. Disease-resistant, prolific-fruited, small-vined varieties of high processing and fresh market quality adapted to machine harvesting are needed now, particularly in the northwestern, central, eastern, and southern production areas. Such diseases as curly top, Verticillium wilt, leaf spots, and fruit rots are causing serious losses in certain areas. Mechanization of the southern tomato and pepper transplant industry is dependent upon the application of basic physiological studies on seed dormancy, germination, and seedling nutrition of tomato and pepper and the epidemiology of several plant bed, disease-inducing organisms that attack these crops. Improvement is needed in the quality of tomatoes harvested mature-green. Lack of fruit firmness, crack resistance, plant and fruit resistance to insects, fruit rot resistance, low pH, and high solids and viscosity for processed products are major problems confronting the tomato processors.

Production problems of peppers are similar to those of the tomato.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, plant pathologists, and horticulturists engaged in both basic studies and application of known principles to growers' problems. Research is conducted at Beltsville, Maryland; Charleston, South Carolina; and Cheyenne, Wyoming; and in cooperation with State Agricultural Experiment Stations at Tifton, Georgia; Logan, Utah; and Prosser, Washington. Tomato breeding and genetic studies at Beltsville, Maryland; and Charleston, South Carolina; involve crossing, progeny selection, disease evaluation, fruit quality evaluation, selection for adaptability, and evaluation for mechanical harvesting capability. At Cheyenne, Wyoming, breeding is directed toward adaptability to the temperature extremes and low humidity of the Great Plains. Breeding for curly top virus resistance is done at Logan, Utah. Disease studies on early blight, gray leaf spot, Fusarium wilt, Verticillium wilt, anthracnose, and tobacco mosaic virus are conducted in controlled laboratory and field experiments at Beltsville, Maryland. Disease research at Tifton, Georgia, includes studies on bacterial spot, bacterial wilt, damping-off fungi, and southern blight of vegetable transplants. Epidemiology of bacterial canker is conducted at Cheyenne, Wyoming. At Prosser, Washington, investigations are directed toward the identification of strains of the curly top virus, variation in virulence of strains on tomato, and nature of resistance to curly top in tomato. Limited varietal evaluation is conducted at Beltsville, Maryland. Work on culture and nutrition of tomato and pepper plants is conducted at Tifton, Georgia.



c. Breeding for resistance to bacterial canker. In cooperation with Wyoming, approximately 100 accessions of Lycopersicon spp. were evaluated in the greenhouse for resistance to bacterial canker. Seven of the more promising ones were evaluated for resistance in the field. Two accessions of L. pimpinellifolium and one of L. esculentum var. cerasiforme, all from the Blood collection in Utah, exhibited highly significant levels of resistance. Crosses were made among these and to susceptible types to improve levels of resistance and study inheritance of resistance.

d. Breeding for resistance to anthracnose fruit rot of tomato. At Beltsville, Maryland, fruit of numerous breeding lines were evaluated in the laboratory for resistance to the anthracnose fruit-rot organism. Four lines, all from the breeding project at the U. S. Horticultural Field Station, Cheyenne, Wyoming, proved highly resistant in repeated inoculation tests. Inheritance studies are underway and crosses have been made to stocks with better horticultural characteristics.

e. Breeding for resistance to insect pests of tomato. In cooperation with the Entomology Research Division, approximately 250 plant introductions were evaluated for resistance to spider mites (Tetranychus telarius), fruit fly (Drosophila melanogaster), flea beetle (Epitrix hirtipennis), leaf miner (Liriomyza munda), and aphids (Macrosiphum euphorbiae and Myzus persicae). The results indicated a wide range of resistance to spider mites, leaf miners, and aphids exists in the stocks. Inheritance studies have begun, and certain crosses have been made to move specific resistances into commercial types.

In South Carolina, low but probably significant levels of resistance to natural populations of fruitworm (Heliothis zea) and southern hornworm (Protoparce sexta) were found among 40 commercial-type tomatoes tested and some selections were made.

f. Breeding for nematode resistance. A program is underway to transfer root-knot nematode resistance from resistant varieties to the widely grown susceptible varieties. STEP 500 is the source of resistance, and Homestead, Floradel, and Supermarket are being used as recurrent parents. Efforts are being made to transfer resistance to Meloidogyne hapla from Lycopersicon peruvianum to L. esculentum.

g. Breeding for high internal fruit color. Genetic studies indicate that the alterations in carotenoid pigment content caused by the crimson mutant are conditioned by a single gene which is recessive and allelic with the gene og for gold flower color. Since it was not possible to show that the crimson mutant and og were identical, the symbol og<sup>c</sup> was proposed to designate the crimson mutant. The gene og<sup>c</sup> is closely linked with the dominant allele of the self-pruning gene (sp) on chromosome 6. An intensive effort is underway to break this linkage and recover the desirable double recessive combination.

h. Breeding for mechanization of the tomato harvest. A continuing vigorous effort is underway to develop multiple disease-resistant breeding lines and varieties that are suitable for mechanization of the harvest. Approximately 100 advanced selections are in grower-type trials at Beltsville, Maryland, New Jersey, Ohio, and elsewhere. Approximately 800 early generation lines are under trial at Beltsville. Many of these will be harvested by machine on a trial basis.

i. Index selection. At Charleston, South Carolina, two generations were processed last year in a study on the effectiveness of index selection under different intensities of inbreeding. Several lines, well above the average in general performance, have emerged from this program, which supports the idea that early-generation sib crossing with index selection is an effective method of tomato improvement.

## B. Diseases

### 1. Tomato

a. Induced sporulation in *Colletotrichum coccodes* (anthracnose fruit rot). A method was developed to induce profuse sporulation by the tomato fruit-rot organism. This organism sporulates very poorly and this characteristic has prevented the development of resistance-evaluation techniques. When grown on V-8 juice agar under continuous white, cool fluorescent light (250 ft-c) the organism produces an abundance of spores that are highly pathogenic to uninjured tomato fruit.

b. Studies on *Pythium* spp. occurring in southern tomato transplant fields. In cooperation with Georgia, *Pythium aphanidermatum* has been shown to cause serious losses in transplant fields. Crop rotation is suggested as a control measure. Crops suggested in such rotations are affected by certain *Pythium* spp. that are also pathogenic to tomato under certain environmental conditions. Studies are in progress to determine interaction of cropping systems, crop debris, moisture, and temperature on the survival and pathogenicity of several *Pythium* spp. prevalent in the soils in which tomato transplants are grown.

c. Physiology and biochemistry of curly top resistance in tomato. In cooperation with the University of California (Berkeley), studies are in progress to determine the nature of resistance to the curly top virus in tomato. Strains of the virus appear highly virulent on tomato although some are mild on sugar beet. An antiserum specific to the virus in leafhopper has been developed.

### 2. Pepper

a. Physiology of the disease development of early blight of tomato and eggplant. In PL 480 research in India, sporulation and nutritional requirements of the causal organism, *Alternaria solani*, were studied extensively.

Certain soluble organic compounds and inorganic elements in healthy eggplant were identified. Acalypha indica was reported as a host for the early blight pathogen.

### C. Culture

#### 1. Tomato

a. Transplant production. There was an increase in uniformity of tomato transplants from about 70 percent marketable to over 90 percent marketable at harvest when grown under adequate nutritional conditions and clipped when 50 percent of the transplants had reached 7 inches in height. Yield trials at several northern locations during a 2-year period indicate clipped transplants perform as well if not better than non-clipped transplants.

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LEAFY AND MISCELLANEOUS VEGETABLES BREEDING  
AND GENETICS AND DISEASES

## Crops Research Division, ARS

Problem. The trend towards mechanization of the lettuce industry continues.

Improvement in irrigation and weed control practices has accelerated this trend. The immediate need is for better methods of planting to insure adequate stands of single-spaced plants. Much research is being concentrated on this area, while research on mechanical harvesting is being held in abeyance because the labor situation has eased. The hazards to production caused by such diseases as big vein, mosaic, lettuce downy mildew, tipburn, and several post-harvest disorders, continue as threats to profitable operations for growers. Lettuce research by the Department is designed to bring some of these diseases under control through the development of adapted and disease-resistant varieties. At the same time the breeder is attempting to incorporate into his disease-resistant material uniformity of emergence and development to reduce growing costs and eventually to provide a "once over" harvest.

Further work is needed to insure production of hardy, high-yielding, and disease-resistant cabbage and broccoli. Continued work is required on breeding and development of spinach breeding lines and hybrids. These attempts to improve the range of plant adaptability and dependable varietal and hybrid performance is in line with increased use of mechanized production and processing.

## USDA AND COOPERATIVE PROGRAM

Research in lettuce is conducted cooperatively with California at Brawley, La Jolla, and Salinas; and at Weslaco in the Lower Rio Grande Valley, Texas. At Brawley, La Jolla, and Salinas we are concerned with the general problem of breeding disease-resistant and adapted varieties for the Southwest. Efforts are concentrated on developing varieties resistant to two destructive virus diseases, lettuce mosaic and big vein, and to Bremia lactucae, the fungus that causes lettuce downy mildew. Cooperative with Texas in the Lower Rio Grande Valley research is aimed at developing varieties resistant to two or more races of lettuce downy mildew and adapted for culture in this area.

At Charleston, South Carolina, work is done to develop basic genetic information and to develop productive breeding lines of cabbage and broccoli that are disease-resistant and of high quality for the Southeast. Cooperative with New Jersey, Maryland, and Texas, work is done at Beltsville, Maryland, to develop multiple disease-resistant and high-quality spinach varieties and hybrids adapted for growth in the eastern and southern areas of the United States.

The Federal scientific effort devoted to research in this area totals 2.8 scientist man-years divided as follows: 2.5 for breeding and genetics; 0.3 for diseases.

### PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 43.0 scientist man-years.

### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

#### A. Breeding and Genetics

##### 1. Lettuce

a. Resistance to mosaic. At Salinas, progress has been made in breeding head lettuce for mosaic resistance. In addition to the resistance found in P.I. 251245 and 251246, another plant introduction from Egypt, P.I. 251247, has some resistance to the virus. Also, a variety from Argentina, 'Galleya', was found to have a higher level of resistance to the virus than the P.I. numbers mentioned above. These resistant selections have been hybridized with commercial varieties, and some lines are now in the second backcross generation.

A study on the nature and inheritance of resistance to mosaic shows that P.I. 251245 type of resistance is probably inherited as a single recessive. This virus is not seedborne in the original L. serriola genotype, but it is seedborne in certain genotypes derived from crosses with commercial varieties. In a second study on the inheritance of necrotic vs. mottling reaction preliminary results indicate that two complementary dominant genes are responsible for the mottling reaction.

b. Resistance to big vein. At the present time big vein is the most damaging disease of lettuce in the Central-Coastal District of California. Merit, a big vein-tolerant variety, is being used as the resistant parent in the breeding program. Two resistant lines developed from crosses with Merit lacked satisfactory horticultural characters. These lines have now been crossed with four of the leading commercial varieties.

c. Evaluation and improvement of lettuce varieties for the Lower Rio Grande Valley, Texas. Several heavy frosts, an epiphytotic of downy mildew, and a poor lettuce market combined to make evaluations of lines in commercial fields difficult during the 1966-67 season. Nevertheless, observations over three growing seasons (including the current season) indicated two advanced early-season breeding lines, M-5 and M-6, are superior to the commonly grown commercial varieties, Great Lakes 659 and Mesa 639. M-5 and M-6 exceeded the checks in general appearance, color, butt appearance, frost resistance, and downy mildew resistance. Seed of these lines is being increased for further testing and possible release. In the mid-season tests,

line M-16 has been outstanding. In comparison with two commercial varieties planted at Rio Grande City it produced about 20% more cartons per acre than Valverde, while the other commercial variety, Great Lakes 6238, was destroyed prior to harvest by mildew and frost. M-16 made larger heads and has a more attractive appearance than Valverde. It was free from mildew damage in these tests. Seed of M-16 is being increased for testing on a large scale and for possible release.

d. Inheritance studies. The inheritance of a new recessive chlorophyll-deficient mutant was determined. These mutant plants have only one-third the quantity of chlorophyll possessed by their normal green sibs. This mutant may be useful in genetic studies.

## 2. Spinach Improvement

a. Breeding line releases. Seed increase of the fall-type line S498 was unsatisfactory and is rescheduled for release in the fall of 1967. Two longstanding smooth leaf and two longstanding Savoy leaf lines are being increased for release to seedsmen during the fall of 1967. One longstanding hybrid (America x 276 x 274) will be released as Supercurl this fall. These lines and the hybrid are highly resistant to two races of mildew.

b. Evaluation of breeding lines. Trials in New Jersey, Maryland, and Arkansas indicate that one longstanding Savoy hybrid, two Savoy, and four flat-leaf lines are adapted for spring production of spinach in these areas.

## 3. Cabbage and Broccoli

a. Studies on inbred-line development. At Charleston, South Carolina, several plants of broccoli and cabbage were found to be highly self-incompatible. The value of these plants has not been established; however, they will be maintained for future breeding and are available to collaborators for production of hybrids.

b. Studies on glaze selections. When glaze (bright green leaves without the "bluish" waxy surface) cabbage is crossed with "bluish" waxy or bloom type, the glaze factor appears incompletely dominant.

c. Quality evaluations. Laboratory tests revealed a variation of dry weight from 6.4 to 9.2% in 149 samples of cabbage, and from 9.7 to 11.5 in 9 samples of broccoli. Soluble solids varied from 3.0 to 7.0% in cabbage and from 5.0 to 9.9% in broccoli. Five samples of cabbage contained over 60 mg of ascorbic acid per 100 grams fresh weight, but the average was 36 mg and the low 26 mg/100 g. Ascorbic acid content of broccoli samples averaged 110 mg/100 g and varied from 80 to 149 mg/100 g.

B. Diseases1. Lettuce

a. Resistance to downy mildew. Seven hundred lines were screened in the greenhouse for resistance to downy mildew. Most of these lines are now in the 5th or 6th generation of selection and are homozygous for resistance to the West Coast race of the disease.

2. Cabbage and Broccoli

a. Resistance to fungus diseases and root-knot nematodes. All the broccoli tested has shown high resistance to Fusarium oxysporum f. conglutinans and cotton root-knot nematode Meloidogyne incognita acrita. Several inbred lines of broccoli and cabbage are showing good resistance to downy mildew caused by Peronospora parasitica which is considered the most severe disease of crucifer species in the southeastern United States.

Our experiments show that broccoli varieties in general have a high level of resistance to root-knot nematode and that the resistance holds up well over a long period of time. Efforts will be made to transfer this resistance to cabbage and other commercial brassicas.

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MUSKMELON AND OTHER CUCURBIT BREEDING AND GENETICS,  
DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Resistance to diseases in widely adapted varieties with good edible and shipping quality are the major factors confronting muskmelon growers. Diseases seriously reduce yields and impair fruit quality of melons in some production regions every year. Muskmelon, watermelon, and cucumber varieties adapted to mechanical harvesting are needed to reduce production costs. Methods to reduce cost of hybrid seed production in melons need extensive study. Improvements in breeding methods are needed to increase efficiency of breeding programs.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program involving geneticists, horticulturists, and plant pathologists engaged in both basic and applied research on melons and other cucurbits. Extensive muskmelon and squash breeding and genetic studies are conducted at La Jolla and Brawley, California; Charleston, South Carolina; and Beltsville, Maryland. Watermelon breeding is done at Charleston. Disease research with emphasis on crown blight of muskmelon is done at Beltsville, Maryland, and at Mesa and Tucson, Arizona, in cooperation with the Arizona Agricultural Experiment Station.

Work on experimental control of morphogenesis in cucurbits is done in Israel under a PL 480 grant.

The Federal scientific effort devoted to research on melons and other cucurbits totals 6.2 scientist man-years: 4.2 are devoted to breeding and genetics, 1.5 to diseases, and .5 to variety evaluation.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 60.0 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Muskmelon

a. Varietal releases. Two years of production of cantaloup varieties Campo and Jacumba, released in 1964 and 1965, indicate their superior crown blight and powdery mildew resistance, yielding ability, and high quality in early spring districts of the West. Seedsmen have expressed increased interest in powdery mildew-resistant Male sterile 1 and Male sterile 2 cantaloups released in 1961 and 1963.

Cantaloup breeding line B66-5, resistant to watermelon mosaic virus 1 and downy and powdery mildew, was released to breeders in 1966.

A standard-type variety especially adapted to production in the humid southeastern part of the United States was released with the name Gulfstream. It has high field resistance to downy mildew and powdery mildew and produces a concentrated set of attractive and relatively early melons with dependable quality and uniform size.

Other breeding work has resulted in the development of a large mildew-resistant Hales type, a small mildew-resistant Hales type, and a powdery mildew-resistant honey dew with a slip-stem characteristic, all of which seem adaptable to production in the Southeast. Also, a fertile white-flowered mutant with pale green cotyledons has appeared in a relative of Gulfstream. Evidently this is a single plethoric gene which affects cotyledon color, flower color, and color of the stigmatic surface.

In a cooperative study with the University of California, crown blight at Five Points, California, was found to be uncorrelated with boron absorption, or with resistance to crown blight in Imperial Valley or to powdery mildew. A line was secured with combined tolerance to boron, to two types of crown blight, and to powdery mildew.

b. Resistance to Alternaria in cantaloups. Verification of a high level of resistance has been obtained in greenhouse tests and resistant breeding lines have been distributed to collaborators in the Southeast. Stock C433 is particularly notable.

c. Powdery mildew and crown blight resistance. A powdery mildew-resistant and crown blight-resistant honey dew breeding line exhibited superior performance to commercial honey dew in both the presence and the absence of powdery mildew in advanced trials in Arizona, California, and Texas. It is in the process of mass-increase for release.

d. Cucurbit mosaic resistance. The delayed backcross program was continued to transfer multiple-factor resistance to CMV into powdery mildew-resistant cantaloup and honey dew. Preliminary results with an airbrush inoculation technique indicate this technique will use less labor and time and provide greater accuracy in eliminating partly resistant suspects. It was equal to inoculation by grafting and required less time and labor.

The successive backcross program was continued to transfer dominant-factor resistance to WMV-1 into powdery mildew-resistant cantaloup and honey dew melons. Mass-selection for fruit quality was practiced in selected populations segregating for WMV-1 resistance.

e. Resistance to nematodes. A number of species of Cucumis are known to carry genes for resistance to the root-knot nematode as well as resistance

to other pathogens. Many attempts to obtain hybrids between C. melo and other species have failed, but crosses between C. sativus and two related wild species, C. hardwickii and C. trigonis, have been made.

f. Resistance to Diabrotica in cucurbits. Techniques were developed to screen large numbers of seedlings for sources of resistance in Citrullus, Cucumis, and Cucurbita. None of the watermelon introductions and only one variety, Sugar Loaf, was resistant. Some of the cantaloup introductions had some degree of resistance and 25 of these proved to be homozygous. Hales Best cantaloup was consistently the most resistant in every test conducted. The fact that Hales Best is in the parentage of most netted varieties may explain why most cantaloup varieties are relatively resistant to Diabrotica. Resistant single-plant selections were obtained from several Cucurbita introductions. Resistant plants were also selected from Cucurbita varieties.

g. Mechanical harvesting. In cooperative work with the University of California, individual melon plants with the bush habit and large fruits with good quality have been secured. The desired combination of characters has not yet been fixed in a true-breeding line.

h. Development of breeding methods. Analysis of within population correlations in the M1 and M9 generations of cantaloup C434-C-3 indicated general improvement in correlations among 16 fruit characters resulting from index mass-selection.

i. Interspecific hybridization. Crosses between cultivars of Cucumis melo x C. dinteri, and between C. melo x C. angolensis set fruit using the wild species as the female parent. It will be necessary to use embryo culture to obtain  $F_1$  plants.

Wild species of Cucumis, related to muskmelon, have been successfully converted to tetraploids as a step toward the production of interspecific hybrids. Crosses have been made between tetraploid muskmelon and certain tetraploid wild Cucumis species. It remains uncertain whether the "hybrid" seed so obtained will prove to be true hybrids.

j. Experimental morphogenesis in cucurbits. In a PL 480 grant with Israel, work was continued to determine methods for studying sex expression in cucurbits at the cellular level. A method was developed whereby the use of labelled DNA and RNA precursors can be used for the study of differentiation of in vitro cultured cucurbit floral buds. Developing female lines of muskmelon through breeding is meeting with some success.

## 2. Watermelon

a. Breeding for polyploids. Numerous attractive tetraploid selections have been obtained from tetraploid hybrids. Some of these have good seed viability. Field pollination to produce trial quantities of experimental 2x

and 3x hybrids were made on a substantial scale. One diploid hybrid performed exceptionally well in regional trials; also one triploid (seedless) hybrid has received many favorable reports from individual observers.

New techniques for conversion from diploid to tetraploid and for identifying polyploids are being devised for watermelons. Tests of polyploids show there is no multiple genome effect on resistance to either race 1 or race 2 of anthracnose.

b. Resistance to anthracnose. A survey to find new sources of resistance of the virulent race 2 of anthracnose has been intensified.

One citron-like relative of watermelon (W1034) has been found to have a substantial level of resistance to the more virulent race 2 and crosses with edible types have been made.

### 3. Squash

a. Interspecific hybridization. In cooperation with entomologists at the University of California, a new species of squash-gourd was discovered from South America that has some desirable characters, and crosses have been made with all of the common cultivated species.

## B. Diseases

### 1. Muskmelon

a. Studies on the mode of natural transmission of the tobacco ringspot virus. In cooperation with Texas, assays were made in the Lower Rio Grande Valley to recover the soilborne tobacco ringspot virus from irrigation water and soil and plant debris from known infection sites. The virus was not recovered from these sites.

b. Additional host for watermelon mosaic virus 2. In Arizona cotton was found to be a host of the virus under experimental conditions. Recovery of the virus was affected by mechanical means but not with its aphid vector.

### 2. Squash

a. Squash stipple virus. A virus inducing systemic bright yellow stippling of Summer Straightneck squash was isolated from diseased specimens growing at Beltsville, Maryland. Fruit production in infected plants is reduced but the fruits are not malformed. Transmission of the virus was effected by mechanical means and infrequently with Myzus persicae.

### 3. Watermelon

a. Internal rind decay of watermelon. In cooperation with Texas, a gram negative, motile bacterium was consistently isolated from internal decaying

spots in the rind of watermelon. This disease is known locally as "dynamite" because of the "explosive" nature of infected melons in the field. Culture filtrates and bacterial suspensions injected into healthy fruit with a hypodermic syringe induced, in part, the disease syndrome.

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FLOWER AND ORNAMENTAL PLANT BREEDING AND  
GENETICS, DISEASES, AND CULTURE AND PHYSIOLOGY

## Crops Research Division, ARS

Problem. The production of ornamental plants grown by florists and nurserymen involves numerous technical problems which may occur during all aspects of the highly varied and numerous growing and selling operations. Cultivars with inherent resistance to disease and insects which are adapted to the expanding urban environment are needed. More decorative and persistent flowers, foliage, and potted plants must be produced to compete for a share of the consumer's dollar. More precise control of growth and the timing of crops should be developed to increase efficiency and to meet specific market demands, and more effort should be devoted to the control of weeds among nursery and container-grown plants. The ornamental plant industry is demanding answers and leadership on how to solve these problems. The great expansion of commercial, out-of-doors cut-flower production and the construction of highly mechanized and automated greenhouses throughout the country bring about many new and unique problems. Explosive urbanization and expanding national, state and local interest in civic beautification create new and urgent need for basic and applied research in the ornamental plant industry. Education in the selection and use of woody plants is urgently needed by the average homeowner. This group of decorative plants, for which consumer demand is highly elastic, must have expanded research effort, consistent with their great expansion of use.

## USDA AND COOPERATIVE PROGRAM

The Department has maintained a long-term research program involving geneticists, horticulturists, pathologists, and physiologists conducting fundamental and applied research which is concerned with the production of ornamental plants grown by florists and nurserymen. The research on breeding and genetics is done at Beltsville, Md., Cheyenne, Wyo., The National Arboretum, Washington, D. C., at Tifton, Ga., in cooperation with the Georgia Coastal Plain Experiment Station, and at Morgantown, W. Va., in cooperation with the West Virginia Agricultural Experiment Station. Research on diseases is conducted at Beltsville, Md., and cooperatively with the Georgia Coastal Plain Experiment Station and the Agricultural Experiment Stations of Oregon, Washington, and West Virginia. Experiments for improving cultural methods and growth regulation are carried on at Beltsville, Md., and in cooperation with the above Experiment Stations.

Reference collections of living plants and herbarium specimens are maintained at the National Arboretum. Promising selections from foreign introductions received through New Crops Research Branch are propagated at the Arboretum for testing and distribution to other botanic gardens, arboreta, and experiment stations. Plant specimens are identified and classified.

Cooperative Agreements are in effect with (1) the West Virginia Agricultural Experiment Station, Morgantown, W. Va., on breeding and genetics of native woody plants of the Appalachian area for potential value as ornamentals, and (2) Oregon State University on lily virus studies. A Grant to Oregon State University provides for study of the mode of action of hydrazine as a physiological regulator of the growth of ornamentals. A Grant to Battelle Memorial Institute, Columbus, Ohio, for the development of analytical methods for fragrance components in rose cultivars and species, is in effect.

The Federal scientific effort now devoted to this area totals 18.3 scientist man-years divided as follows: Breeding and Genetics 7.2; Diseases 2.8; Culture and Physiology 4.7, and Systematic Biology 3.6.

The scientific effort devoted to the Extramural Research Program totals 2.2 scientist man-years divided as follows: Breeding and Genetics 0.4; Diseases 1.2, and Culture and Physiology 0.6.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 152.0 scientist man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

1. African violets. Cyto-histological proof of the single cell origin of plantlets in 13 species of Saintpaulia was obtained.
2. Azaleas. Colchicine treatments were applied to produce tetraploids of some of the commercial cultivars of forcing azaleas. The affected polyploid sections were isolated from otherwise sterile plants. Species hybrids are now being obtained in this program to develop a yellow, evergreen azalea.
3. Carnations. At Cheyenne, Wyo., a technique for histological and cytological identification of the various levels of ploidy, including cyto-chimeras, was developed for Dianthus species. Breeding studies were initiated with polyploid carnations and with seedlings from the world collection of garden carnations. Over 5,000 seedlings were evaluated as sources of germplasm in the development of carnations which are disease resistant and whose flowering can be controlled.
4. Cornus. At Cheyenne, Wyo., seedling markers (pigmentation of radicles and/or hypocotyls) were found to be potentially useful in the breeding of Cornus species.

5. Cotoneaster. At Cheyenne, Wyo., interspecific crosses in the genus Cotoneaster yielded one or more  $F_1$  seeds in 21 new combinations.

6. Crape-Myrtle. Four new selections of Lagerstroemia indica were named for release in 1967: L. indica 'Catawba', L. indica 'Conestoga', L. indica 'Potomac', and L. indica 'Powhatan'. Selection was based primarily upon increased mildew resistance and improved flowers and growth habit.

7. Daylilies. Tetraploid seedlings of induced tetraploids of selected diploid clons were transplanted to the field for performance trials. From the first year's data, repeat blooming, a desirable characteristic, was found to be recessive and was controlled by many genes.

8. Geraniums. Chlorophyll variegations in geranium are due to changes in genetic material carried in the plastids themselves. Some of the mutants observed in geraniums are the result of change in, and not loss of, genetic material.

9. Holly. The following six holly selections have been internationally name-registered and are being readied for distribution: Ilex (aquifolium X cornuta X leucoclada) 'Clusterberry', female; I. (myrtifolia X opaca) 'Oriole', female; I. (integra X pernyi) 'Accent', male; I. (integra X pernyi) 'Elegance', female; I. (X koehneana) 'Jade', male; and I. (X koehneana) 'Ruby', female. Cooperative holly test areas have been established in Aurora, Ore.; Wooster, Ohio; Oak Ridge, Tenn.; and New Brunswick, N. J.

10. Lilies. (a) Polyploids. Two tetraploid Easter lily clons were selected from the many clons available and were sent out to commercial lily growers for trial. (b) Backcross populations. A small lot of seed was obtained from a backcross generation of L. speciosum album rubrum X the amphidiploid 'Black Beauty'. If the assumption is correct, this will be the first seed obtained with 'Black Beauty' and will allow for the hybridization between the Oriental hybrids complex (4 species) and the Aurelian hybrids group (8 species).

11. Magnolia. Several tree-type seedlings of interspecific hybrid magnolia have flowered for the first time. They are generally pink-flowered and show close resemblance to M. denudata. Seven seedlings of M. liliflora X stellata have been selected for naming.

12. Philadelphus. At Cheyenne, Wyo., the requirements of light in relation to stratification and germination of seeds of Philadelphus were investigated. The temperature range for germination of stratified seeds in darkness was 0 to 5°C, but 5 to 10°C was effective in promoting germination in the presence of light. Light applied during germination enhanced germination, while light applied during stratification had a limited effect on subsequent germination. Eight or more hours of light at or near the end of the stratification period improved germination.

13. Poinsettias. (a) Cytology. The Mikkelsen cultivars of poinsettia were shown to be a series of periclinal chimeras with a mutation to no pigment formation occurring in the epidermis and then moving into the internal histogenic layers. This research shows that a chromosomal factor for pigment formation will produce the same patterns of variegation as cytoplasmic factors for chlorophyll formation because the patterns are a reflection of the contribution of the several histogenic layers in ontogeny. (b) Breeding. Six lines of poinsettia breeding material were released to commercial breeders. Crosses were made for selection of cultivars as well as for development of true breeding, seed-propagated cultivars. (c) Genetics. Additional genetic and chemical proof of the independence of certain genes controlling anthocyanin development in leaves and flowers of poinsettia was found. Paper chromatographic analysis showed that the anthocyanins in certain pink and red poinsettia bracts were identical but present in greatly reduced quantities in the pinks.

14. Pyracantha. Chromosome determinations for an additional 26 species and cultivars have been completed. All have shown a chromosome compliment of  $2n = 34$ . Crosses in 1966 between Pyracantha and such related genera as Sorbus, Crataegus and Malus produced seed but germination has been generally poor. Extreme weather conditions during late winter have permitted a rigid hardiness selection of field grown seedling populations.

15. Roses. Seedlings of rose species resistant to seven isolates of Diplocarpon rosae are being screened in an intensive breeding program. Seedlings of Rosa rugosa that are showing some resistance to D. rosae are undergoing colchicine treatment to double their chromosome number.

16. Viburnum. Hybridization with deciduous and evergreen species of the section Lantana have resulted in good seed set and good germination to date. The following eight improved selections were named for 1967 release as follows: Viburnum X rhytidophyllum 'Alleghany'; V. dilatatum 'Catskill'; V. dilatatum 'Iroquois'; V. lantana 'Mohican'; V. (dilatatum X lobophyllum) 'Oneida'; V. sargentii 'Onondaga'; V. sargentii 'Susquehanna'; and V. sieboldii 'Seneca'.

## B. Diseases

1. Chrysanthemum. Aspermy - The British type culture of tomato aspermy virus completely suppresses viable seed development in tomato fruits. Although serologically related viruses isolated from chrysanthemum are related to tomato aspermy, these viruses are not true aspermy types since they do not completely suppress tomato seed development.

2. Iris. Mosaic - Both mild and severe mosaic virus diseases of Dutch iris have been identified in bulbous iris in the United States. Severe mosaic often remained latent. Although no foliage symptoms were produced, the virus was detected serologically. Infected iris bulbs which do not produce severe mosaic foliage symptoms during one growing season, may show strong mosaic symptoms the following year. Because of the delayed symptom expression of the severe mosaic virus, it is not likely that field roguing will completely control this virus.

3. Pansy. At Tifton, Ga., the cause of a serious disease among pansy plant growers was found to be Cercospora acerina, not previously reported in the Deep South. This disease can be controlled by proper use of fungicides in a routine spray program.

4. Rose. Blackspot - Eighteen of 20 roses most resistant to Diplocarpon rosae from 7 geographic locations were species or specie hybrids. No symptoms developed on leaflets of the Rosa rugosa, and no conidia were recovered from R. sp. cv. 'Lasca', one clon of R. multiflora, or one clon of R. X alba. Infection peaks of D. rosae in early spring and late summer were attributed to variability in host rather than in the inoculum.

#### C. Culture and Physiology

1. Accelerated growth of seedlings in controlled environments. Seedlings of selected  $F_1$  hybrid annuals were germinated directly under intermittent mist in the greenhouse for 7 to 10 days and were transferred to specially designed plexiglass growth chambers to study the interactions of light, temperature, atmospheric composition ( $CO_2, H_2O$ ) and velocity, nutrient supply, growing media, and watering procedures. Seedlings exposed to high intensity fluorescent light and supplemental incandescent light (2000-2500 ft-c.) for 16 hours daily under controlled conditions produced greater leaf numbers, larger leaves, heavier shoots, greater branching, and earlier and more abundant flowers than those grown in the greenhouse under routine cultural procedures. All plants tested showed marked carry-over effects when the plants were transferred to the greenhouse following controlled environment treatments. (Cooperative with the Agricultural Engineering Research Division.)

2. Easter lilies. Artificial light to accelerate flowering can apparently partially or completely replace low-temperature storage conditioning of commercial and tetraploid Easter lily bulbs for this purpose. The Georgia Easter lilies were plunged in beds out-of-doors in Georgia. The bulbs had not been vernalized and produced rosetted plants. Lighting of the rosetted plants with incandescent light from 10 p.m. to 2 a.m. resulted in quicker bloom and shorter plants than observed on plants grown without the lighting. This technique should allow the use of large Georgia lily bulbs for pot plants with only a slight reduction in the

number of flowers. Large bulbs in the past have always produced plants too tall for pot culture. (Cooperative with the Georgia Agricultural Experiment Station).

Fertilization of lilies grown in the field. At Tifton, Ga., ureaform and superphosphate fertilizers increased the number of lily flowers which developed during forcing but also caused an undesirable tipburn of the leaves. The yield of lily bulbs in the field was not increased by the application of nutrient sprays, or by addition of fertilizers in different amounts and at different intervals from that used by the commercial growers. (Cooperative with the Georgia Agricultural Experiment Station.)

3. Identification of pigments in red cornflower. The anthocyanins in the flowers of Centaurea cyanus cv. 'Red Boy' (cornflower) were isolated and identified as pelargonidin-3-5, diglucoside; pelargonidin 3-5, diglucoside acylated with caffeic acid; and a trace of cyanidin 3-5, diglucoside. The fact that this tissue contained primarily anthocyanins which did not have di-ortho-hydroxyl groups accounted for its red color even though the red flowers contained the same amounts of iron and co-pigment as was found in the blue cultivar.

Isolation of pigments in blue cornflower. Six grams of blue pigment was isolated from the flowers of 1 acre of Centaurea cyanus cv. 'Blue Boy' (cornflower). The pigment was approximately 60 percent pure; its purification was accomplished by the utilization of electrophoresis in a glycerine density gradient. Also isolated from this tissue was 700 mg of the "bis-flavone" co-pigment. The individual flavones were separated by preparative thin-layer chromatography on cellulose plates. Research is in progress to identify the structure of the blue coordination complex found in blue cornflowers.

4. Chemical pruning of horticultural plants. A survey has been completed concerning the horticultural utility of the chemical pruning agents of the fatty acid ester group. Over 120 species of annual, perennial, and woody plants were tested. The responsive species were vegetative plants with hairy leaves and had formed distinct nodes. Less responsive were plants forming flower buds, or had waxy leaves or grew in flushes; they were chemically pruned with difficulty. Plants with enclosed growing points, in dormancy, and in the seedling stage of growth were not chemically pruned by any dosage tested. The plants were either non-responsive or exhibited little selectivity between tissues.

Surfactant regulation of chemical pruning action of organic solvents. Many aliphatic and aromatic organic solvents chemically pruned chrysanthemum plants. The selective action depended on the use of the proper surfactant. Surfactants with the proper hydrophilic-lipophilic balance emulsified, regulated the penetration, and allowed the organic compounds to exert their caustic action. The only effective surfactants out of

over 240 evaluated for preparing the emulsions, were a polysorbate and a polyoxyethylene ether-polyoxyethylene glyceride alkyl aryl sulfonate blend. Other surfactants which were more hydrophilic or more lipophilic than the two kinds found, made the emulsions ineffective over a wide concentration range.

5. Phytochrome regulation of chrysanthemum flowering. Far-red was inhibitory to flowering at the end of an 8-hour photoperiod when the following 16-hour dark period was intermittently interrupted with cyclic fluorescent illumination (CFL). Plants grown with an interpolation of a 4-hour dark period following the 8-hour photoperiod and 12 hours of CFL were in vegetative growth. One minute red light following the 4-hour dark period and prior to 12 hours of CFL repromoted flowering and was immediately re-inhibited with far-red. Phytochrome was thus regulating the flowering of chrysanthemums, an obligate short-day plant, and the chrysanthemum was exhibiting under these special conditions, all of the characteristics of a long-day plant. (Cooperative with the Pioneering Laboratory of Plant Physiology.)

#### D. Systematic Biology

1. Herbarium collections. An addition of 30,000 specimens to the herbarium research collections has included material from a variety of foreign and domestic sources. Staff collections of cultivated plants of the gardens, nurseries, and experiment stations of the southeastern States are being documented in accordance with needs for a future manual to cover the resources of this geographic area.

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SHADE, ORNAMENTAL AND WINDBREAK  
TREE BREEDING, DISEASES AND CULTURE

Crops Research Division, ARS

Problem. Research is needed to find more effective and less costly disease-control methods for shade tree diseases. Because the use of DDT has been prohibited in some cities and is in disrepute elsewhere, a new control for Dutch elm disease is urgently required. The loss of elm trees has increased the demand for new trees better suited to modern highway, city, and home designs. In the Great Plains, establishment of trees for farm windbreaks is difficult. Studies of ways to ensure survival of newly planted trees are fundamental to economic windbreak establishment. Substantial factual information is required on the effect of windbreaks on improvement of living conditions for men, on farm livestock, and crop production in order to guide design planning and choice of windbreak species.

## USDA AND COOPERATIVE PROGRAM

The urgent need for more effective methods to combat Dutch elm disease dictated that the disease receive priority in our research on shade tree diseases. The Dutch elm disease problem receives special attention at Beltsville, Md., and at Delaware, Ohio. At Tifton, Ga., mimosa wilt is the only problem under study. Work on live oak canker and sweet gum blight was discontinued during 1966. At Mandan, N.D., research continued on the effects of windbreaks on crop yields. At Cheyenne, Wyo., study of the culture and propagation of trees for farmstead windbreaks is in progress. At Tucson, Ariz., research on the cause and control of lethal rot of saguaro is conducted. The research at Delaware, Ohio, is cooperative with the Ohio Agricultural Experiment Station, at Tifton, Ga., with the Georgia Agricultural Experiment Station, and at Tucson, Ariz., with the University of Arizona and the National Park Service.

The PL 480 project in The Philippines on cadang-cadang is cooperative with the College of Agriculture, University of the Philippines.

The Federal scientific effort assigned to this area totals 9.2 scientist man-years divided as follows: Breeding 0.5, diseases 4.7, culture 4.0.

## PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 18.0 scientist man-years.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding

1. Elm. Four shoot cuttings of the tetraploid *Ulmus pumila* were rooted under mist in 1966. These rooted cuttings are insurance against accidental loss of the original tetraploid. Also, rooted cuttings having the histogenic composition 4-4-4 were produced from a plant having a 2-4-2 histogenic structure. The conversion to 4-4-4 was accomplished by taking shoots from root cuttings and then rooting the shoots under mist. Shoots from root cuttings arise from the second histogenic layer and their chromosome number is the same as cells in that layer. No natural tetraploids were found among several hundred shoots from untreated root cuttings of *U. pumila* and *U. parvifolia*.

2. Mimosa. In Georgia, selections of wilt resistant mimosa were increased in anticipation of eventual release.

B. Diseases

1. Elm. Dutch elm disease reduced the velocity of organic solute translocation in 30-year-old American elms. A decline of 80 percent in carbon  $^{14}$  transport 2 weeks after inoculation with *Ceratocystis ulmi* was recorded. A low-cost plastic chamber was devised and constructed for use in measurements of photosynthesis in healthy and in diseased elms. A technique was developed for labeling spores of *Ceratocystis ulmi* with radiocarbon. Evidence was obtained that 3-month-old American elm seedlings inhibit spread of the fungus in the inoculated seedling and eventually possibly destroy it. The fungus could not be isolated 16 weeks after inoculation into trees 3 months old at the time of inoculation. The cause of the failure of the fungus to survive was not determined. Spore load of inoculum was not important in final severity of disease in inoculated young trees. Twelve weeks after inoculation of 8-year-old elms severity of disease was equal in trees inoculated with spore suspensions containing  $10^2$  or  $10^6$  spores per ml. A *Fusarium* root rot of elm was described.

2. Mimosa. Mimosa trees dying from the wilt disease frequently produce a heavy seed crop. The wilt organism, *Fusarium oxysporum* f. *perniciosum*, was cultured from surface sterilized seed taken from diseased trees. Shipment of infected seed could, therefore, be a means of spreading the disease to non-infested areas. Infected seed could also be a source of disease in seedlings grown for experiments in sterilized soil.

3. Saguaro. In cooperation with the University of Arizona and the National Park Service, new evidence was secured about survival in soil of the bacterium that causes lethal rot of saguaro. The bacterium, *Erwinia carnegieana*, the cause of saguaro rot, survived brief exposure to  $55^{\circ}\text{C}$  in

dry soil and the bacterium survived in soil beneath rotted saguaros. Saguaro seedlings rotted following puncture inoculation with soil contaminated with *E. carnegieana*. The bacterium failed to infect unwounded saguaro flowers that had previously been insufflated with dry, dusty soil contaminated with *E. carnegieana*. *E. carnegieana* was isolated from soil beneath rotted saguaro but could not be isolated from soil obtained from localities several miles from stands of saguaro. However, the pathogen was isolated from soil in open areas between rotted saguaros. Lack of saguaro reproduction in Saguaro National Monument may be due, in part, to death of seedlings infected by bacteria that survive in desert soil. Temperatures of 35°C to 40°C were more favorable than lower temperatures to severity of rot in inoculated saguaro. Mortality of saguaro in the test plots at Saguaro National Monument was 2.0% in 1966.

### C. Culture

1. Materials, production and management of farmstead windbreaks. Series of one- or multiple-row windbreaks planted at intervals of 20 or 40 rods across fields to reduce soil blowing, and sand-blasting of crops, and to trap snow for increasing soil water, have no cumulative effect in reducing wind velocity or in trapping snow. When identical species of like age and spacing distance in the row are used, snowdrifts on the leeward sides of belts and wind velocities between belts are identical. North-south belts form deep, narrow drifts and east-west belts form drifts 3 to 4 times wider and about half the depth of the north-south ones. About the time of the first spring thaw, about March 15 of each year, snowdrifts have a density of about 43 percent. The drifts form a potential water tank averaging 3.5 to 4 feet deep, up to 40 feet wide, and of the length of the windbreak. Sufficient water is present to spread 2-3 inches over an area 15 to 25 times the width of the drift or most of the area between 40-rod belts. Topography frequently prevents this spread and confines the water to the drift area. Sheet and gully erosion result. Some progress is being made to accomplish a wider distribution of snow and resultant water by (1) increasing the spacing of trees in the row, and (2) by removing lower branches from existing trees.

2. Crop-plant response to field windbreaks. Wind barriers erected across fields yielded further data on their influence in reducing wind velocity and increasing soil water and crop yields. These wind barriers increased over-winter buildup of soil moisture from trapped snow out to 14 times the barrier height in the top 6 feet of soil on the leeward side. The increase on the windward side did not extend beyond 6 heights and did not penetrate deeper than 4 feet. Wheat yields in the first 20 and 25 barrier heights were 12 and 8.5 bushels, respectively, greater on the leeward side. Deep snowdrifts formed on either side of barriers caused an unfavorable reverse wind action on their leeward sides. This action clears the land of all snow for some distance beyond the drift. It can be corrected only by providing windbreak structures with more porosity in their bottom parts which, in turn, will produce wider and more shallow snowdrifts.

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## REPLACEMENT CROP INTRODUCTION AND EVALUATION

Crops Research Division, ARS

Problem: The agriculture of the United States is based on crops which have originated outside our borders. Selection and development of new varieties to fit environments of new areas, to provide superior sources of food and feed proteins or other nutritional qualities, to supply new raw materials for our advancing industrial and medical technology, and to improve existing crop varieties in any number of important characteristics are dependent upon a continuous flow of introduced germ plasm. Inherent in this is the preliminary evaluation and characterization of plant introductions for traits useful to plant breeders throughout the world and the systematic storing and retrieval of this large amount of useful information. The perpetuation of valuable germ plasm through maintenance plantings and long-term seed storage is a necessary adjunct of this program of research.

## USDA AND COOPERATIVE PROGRAM

The nature of this program is to conduct investigations concerned with the introduction, evaluation, and maintenance of plant germ plasm in support of a strong and diversified agriculture for the United States. Both basic and applied research is undertaken in the areas of: economic botanical assessment of the world's plant resources and exploration for diverse germ plasm in the world centers of crop origins; agronomic, horticultural, and pathological evaluation of introductions as breeding stocks through a national cooperative program for sources of natural resistance to crop pests, as potential new crops, and for other uses brought about by shifts in agriculture and industrial and medical technologies; and the preservation of important segments of germ plasm either as seed or as vegetative stocks. Leadership for this program is at Beltsville, Maryland.

Four national introduction stations are responsible for evaluation, maintenance, and/or quarantine of new introductions which require special handling: Chico, Calif., Miami, Fla., Savannah, Ga., and Glenn Dale, Md. The responsibility for preservation of seed stocks of national interest lies with the National Seed Storage Laboratory, Fort Collins, Colo. Cooperative new crops studies to determine significant agronomic characteristics of plants having valuable end-products are conducted cooperatively with Experiment Stations of Montana, Nebraska, North Carolina, and Oregon. Four regional introduction stations and one interregional station deal with the evaluation of crop breeding stocks basic to plant improvement programs of Federal, State, and Private research organizations.

A contract has been established at Lafayette, Ind., to investigate the crop developmental problems of Vernonia anthelmintica, a natural source of epoxy acid in the seed oil.

Fourteen PL 480 projects are active, all dealing with research on the collection and evaluation of native plants of potential use in the agriculture of the United States. The countries and number of projects are as follows: India - 8, Israel - 1, Korea - 1, Pakistan - 2, Turkey - 1, Yugoslavia - 1.

The Federal scientific effort devoted to research in New Crops totals 38.0 scientist man-years. Of this number, 3.0 are devoted to international plant exchange, 3.3 to botanical investigations, 6.6 (1.8 on AID funds) to special plant procurement and related botanical activities. Research on new crop evaluation includes 8.5 scientist man-years for horticultural research, 4.3 for agronomic studies, 4.8 devoted to evaluation of potential new crops, 4.5 to pathology, and 3.0 to maintenance of germ plasm.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 31.0 scientist man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Plant Introduction

1. Breeding Stock Introduction. International plant exchange in 1966 resulted in 7,581 acquisitions and 1,752 shipments were made to 116 countries. Forage plants (2,308), vegetables (2,193), and cereal grains and sorghum (1,116) constituted the major introductions.

a. International exchange. Collections of special significance included 334 items from the Soviet Union and associated "bloc" countries. PL 480 projects supplied 167 grasses and legumes (Spain) and 309 oats (Avena) (Israel). Cooperation with the University of Reading, England, provided a valuable collection of 711 small grains and 116 forages from Afghanistan.

b. Foreign exploration. Two major field explorations were accomplished: (1) Mexico for beans (Phaseolus), 305 collections; and (2) Korea for ornamentals, 537 collections. The final inventory was completed for the 1965 Jones-Keller expedition to the Soviet Union. This expedition added 1,075 forage plant accessions to U.S. breeders' gene pool. Through cooperation with Oklahoma State University, 150 dryland forage species were collected in Mexico and Texas and will be placed on inventory after increase.

c. Domestic exploration. Collection of woody ornamentals from the Great Plains States was completed, the project to collect native and naturalized forage species in Alaska was initiated, as well as one for native blueberry (Vaccinium) species in the Appalachians. The latter produced 23 items with larger numbers anticipated in 1967-68.

d. Support for AID missions. Requests for experimental plant materials to support these programs were less than for 1964-65 but technical assistance through providing advice and recommendations increased. Personal conferences between Beltsville and AID field personnel were more frequent than in previous years and this should lead to even more efficient programming in the future. Requests for plant materials came from 32 countries and resulted in 54 shipments composed of 1,000 items. The greatest activity occurred in the Latin American Region and may be a partial reflection of direct field contacts made during early 1966.

The cacao, coffee, and rubber collections, being maintained at the Miami Plant Introduction Station, are continuously being used to fill requests from AID and other research programs in the tropics. Cacao breeding stocks are in greatest demand. Through periodic surveys by qualified virologists, there is now a total of 185 virus-indexed cacao clones available for distribution. An inventory of clones being held at Miami and Mayaguez will be issued in 1967.

e. Maintenance of germ plasm. Total accessions in the National Seed Storage Laboratory now number 53,000, an increase of 10,000 over 1965. Major emphasis is being directed toward acquiring valuable genetic stocks such as the Blakeslee Datura and the Cleland Oenothera collections. These and other collections have been thoroughly studied cytogenetically and represent documented materials for future research.

Storage temperatures and humidities in use appear to be quite satisfactory. Only 50 lots of the hundreds entering storage in 1961 will require revitalization in 1967. Research for the effect of flexible moisture barriers on seed longevity over a range of temperature and humidity values has been underway for four years. Of the 24 materials tested, 13 have allowed only minor losses of viability over an 18-month period. One product, a fluorohalocarbon material, permitted retention of full viability of seed of originally 5 percent moisture content for a period of 48 months at 90°F. and at 90 and 70 percent relative humidities.

Project work was completed in 1966 in determining whether seed longevity of varieties within the same species varies significantly. Statistical treatment of the data indicates that it does.

Supplements No. 2 to the first inventories prepared in 1962 were prepared in 1966 covering corn, cotton and fiber, oilseed, small grains, sorghums, and vegetables now in the NSSL.

Progress was made in publishing the backlog of the regular series of Plant Inventories. Nos. 164, 165, 166, and 167 were printed and Nos. 168 and 169 should appear in 1967.

f. Research on centers of crop origins. Based on phytogeographic studies of Cucumis and its insect and disease pests, we now have better information

on probable primary and secondary centers of origin of this genus of economic plants. Future explorations for germ plasm of this genus will greatly benefit by this additional background knowledge.

Similar studies have been applied to beans (Phaseolus) and will be undertaken on peanuts (Arachis) and soybeans (Glycine).

## 2. Plant Resources.

a. Plant taxonomy and nomenclature. The taxonomic study of the important grass genus Lolium was completed. This resulted in a comprehensive taxonomic revision of the genus which will be published as a USDA Technical Bulletin.

Field study and collection of Vernonia, section Stengelia, source of seed oil high in epoxy oleic acid was completed during the year. This field work yielded an extensive collection of seed of Vernonia species which will provide a basis for further chemical and agronomic evaluations of the genus as a new oilseed crop. Field data along with information previously accumulated from herbarium studies will form the basis of a thorough taxonomic monograph of this group of plants.

During the year a total of 211 USDA scientific manuscripts were checked for accuracy in use of scientific names of plants; 709 plant specimens and 2,090 seed samples were identified.

b. Botanical investigations of new crops. The seed oils of Crepis, a large genus of the tribe Cichorieae, are rich in crepenynic acid and vernolic acid. During this reporting period, seed samples of several additional species were obtained from PL 480 countries. A Turkish sample of C. alpina contains 74% crepenynic acid, the highest percentage discovered to date. The sections of the genus containing both high vernolic and high crepenynic species are Old World in distribution with the highest concentrations of species in the Mediterranean region.

Substantial concentrations of crepenynic acid have also been encountered in two genera of the tribe Cichorieae closely related to Crepis: Lapsana communis (50%) and four species of Picris (30-46%). The occurrence of high concentrations of crepenynic acid in these genera as well as Crepis, greatly increases the possibility of discovering high percentages of crepenynic acid in plants having good crop potential.

A paper evaluating the seed of 379 species as potential sources of protein for food or feed was prepared for publication. Seed proteins from a number of the species have a better pattern of essential amino acids than many crop seeds. This research gathers impetus from the present world shortage of protein and the greater shortage that is predicted.

Seed of 194 species representing 56 genera of the Labiatae were analyzed for oil and protein content and for fatty acid composition. A botanico-chemical paper reporting on this research was submitted for publication. The seed oils of the Labiatae include many containing high concentrations of oleic, linoleic, and linolenic acids. A number of the oils contain unidentified or recently characterized fatty acids including laballenic and other allenes, hydroxy acids and several others that appear to be C<sub>18</sub> trienes and probably some unusual ones with less saturation. Such unusual oils and fatty acids have potential value in industry. Our present information indicates that a search for additional species rich in laballenic acid would most profitably be made among the members of subfamily Stachyoideae and particularly among the species comprising the tribe Stachydeae. Oils from all 13 species of the genus Teucrium contain trans unsaturation in unidentified components. Two species of Lamium contain allene in addition to trans unsaturation and two species of Thymus appear to produce hydroxy acids. Knowledge of the correlation between such chemical constituents and related plant groups can provide considerable guidance for future screening efforts.

PL 480 projects continued to supply practically all of the samples entering the seed screening program during the reporting year. India supplied 62 samples; Korea 32; Pakistan 170; Spain 41; Sweden 11; Turkey 190; and Uruguay 73, for a total of 579 samples. As valuable as these collections are, general screening alone is not enough. Intensive follow-up botanical studies are needed to evaluate the crop potential in selected plant groups and only staff botanists can do this job effectively.

The seed oil and protein screening program continues to produce a wealth of promising leads to new and unusual constituents. During the reporting year 29 species were selected for further agronomic and chemical study.

c. Anticancer screening. A total of 1,608 plant samples were supplied to laboratories designated by the Cancer Chemotherapy National Service Center for preparation of extracts for anticancer screening. This number includes 1,512 samples for preliminary screening, 21 recollections of preliminary actives for completion of screening, and 75 recollections of confirmed actives.

Several laboratory prepared derivatives of camptothecin, isolated from Camptotheca acuminata, are now known to show equivalent or better anti-leukemic activity than the parent compound. The supply of Camptotheca for isolation of additional camptothecin is adequate for immediate needs. An additional 5,000 seedlings were established to assure an adequate supply two to three years hence. An active chemical constituent with possibly better anticancer activity than the active constituent of Camptotheca acuminata was isolated from another plant. Very promising antileukemic activity was detected in a crude extract of an accession from Turkey.

d. Vegetation studies of tropical regions. In continuation of Publication CR 49-65, entitled "Vegetation of Southeast Asia: Studies of Forest Types 1963-65," issued in December 1965, considerable time has been devoted during the past year to the preparation of a comprehensive report on the forests of Southeast Asia and their correlation with Puerto Rico and Texas. This supplemental report contains a detailed discussion of various types of forests, savannas, bamboo and palm brakes, climate and soil patterns of the five countries of the Mekong basin countries, and their affinities or contrasting features in Puerto Rico and Texas. Information is given on plants that develop as secondary or successional growth following cutting and clearing or after treatment with chemicals. Other information included is a treatment of useful and toxic or otherwise injurious plants, especially the most common ones found in the Mekong basin countries, and the parts of plants that may be eaten and method of preparing them for use in times of emergency.

The report will include a series of maps and illustrations, to complement those published in the first report. Judging by the constant demand for the first report issued in December 1965 on the "Vegetation of Southeast Asia," the report now in press should be of considerable value to the military, especially in field operations.

#### B. New Crop Evaluation

Evaluation of Breeding Stocks. Research emphasis is directed toward evaluation of plant introductions as sources of genetic variability to improve crop quality, varietal resistance to pests and diseases, and to develop new industrial, agronomic, and horticultural crops through Federal and regional cooperative programs.

##### 1. Horticultural Crops.

a. Fruits and nuts. Growers' interest in the Chinese Gooseberry (*Actinidia chinensis*) continues to increase as this new fruit becomes better known. One grower at Corning, Calif., propagated seedlings during the year to plant 40 acres. This brings the total reported to 67 acres. Eight hundred pounds of fruit were harvested from 12 vines belonging to a cooperator at Paradise, Calif., and were sold readily for an undisclosed price to a restaurant chain..

Information is being gathered on the insects responsible for pollinating Chinese Gooseberry flowers at the Chico Station. Thus far six species have been observed on the male flowers and nine on the female. The first crop from the field trial of Chinese Gooseberry varieties introduced from New Zealand totaled 1,300 pounds of fruit from 0.41 acre.

Trees of 10 almond varieties introduced as seed from Italy in 1959 have flowered at Chico for two years. Among these seedlings are individuals with first flowers opening as late as April 13. Commercial almonds start

to bloom in late January or early February, depending upon weather conditions, and the flowers often are killed by frost.

A precocious flowering characteristic has been identified at Chico in seedlings of English walnut introductions. Some seedlings fruited in their second growing season. The genetics of the character are being studied.

At Glenn Dale, the major emphasis in research with fruit introductions continues on virus studies. Efforts to detect virus infections in apple, pear, and grape introductions using seedlings of Chenopodium quinoa as herbaceous indicators led to the discovery of a seed-borne virus (CQV) in this valuable indicator plant. An antiserum for detecting it in quinoa was prepared at Glenn Dale. All quinoa seed now used in the program is from virus-negative parents.

Evaluation of tropical and subtropical fruit introductions at the Miami station again was set back by a hurricane. The 1966 storm caused less breakage of tree branches but more extensive salt burn than storms experienced in 1964 and 1965. In spite of this interference the mango evaluation program has shown seedling progenies of certain parents to be much more precocious than others. Five seedlings were selected for further testing of fruiting characteristics.

In cooperation with members of the NC-7 Technical Subcommittee on Fruit Crops, the Minnesota Agricultural Experiment Station published descriptions of plant introductions and hybrids of plant introductions as Technical Bulletin 252, Prunus hybrids, selections and cultivars, at the University of Minnesota Fruit Breeding Farm.

b. Vegetables. The collection of vegetable germ plasm was again expanded during the year. Numerous collections of Phaseolus vulgaris, including both wild and cultivated types, were added to the collection. The wild material appears particularly promising as a source of genes for disease and insect resistance, particularly to Fusarium root rot.

In the Regional Plant Introduction Program the four cooperative stations grew vegetable plant introductions as follows for evaluation and seed increase:

NC-7, Ames, Iowa	820	accessions
NE-9, Geneva, N.Y.	1,500	"
S-9, Experiment, Ga.	1,080	"
W-6, Pullman, Wash.	844	"

Included are both recent introductions being grown for the first time and older introductions being increased to maintain seed viability.

At the Nebraska Agricultural Experiment Station six tomato introductions out of 394 tested showed resistance to 2,4-D spray injury. One of these, P.I. 129131 from Panama, appears promising for use in breeding programs.

Out of 99 carrot introductions screened for resistance to root knot nematode at the Regional Station, Ames, only one (P.I. 174206) was as resistant as Early Chantenay.

With the cooperation of the other three Regions, the Northeast Regional Plant Introduction Station, Geneva, published a list of pea introductions (Pisum sativum) having resistance to the diseases, insects, and nematodes attacking this crop.

The Delaware Agricultural Experiment Station released a new cantaloupe variety with resistance to downy and powdery mildew, and to Alternaria leaf spot. Resistance was attributed to P.I. 123517.

Plant breeders in South Carolina report the release of 'Gemini' and 'Cherokee' cucumbers. Both new varieties derived multiple disease resistance from P.I. 197087 and P.I. 220860.

The Western Regional Plant Introduction Station started to evaluate and increase the more than 2,000 bean introductions received as a result of the exploration program in Central America and Mexico. Predominant among the introductions grown in 1966 were dry bean types with vine or semi-vine habit.

The University of Arkansas released the 'Pope' tomato for green pickling. It was derived from a cross of P.I. 79532 X 'Roma'. It inherited high resistance to Fusarium wilt from both parents since 'Roma' also has the same plant introduction as one parent. The 'Harvester' tomato, released by the USDA also carries Fusarium wilt resistance from the same source.

The Missouri Agricultural Experiment Station published as Research Bulletin 908 the detailed analyses of 250 plant introduction tomatoes for acidity and soluble solids.

'Dixie Savoy' spinach released jointly by the USDA and the Texas Agricultural Experiment Station contains genes for resistance to blight from P.I. 20026, and to two races of downy mildew from P.I. 140464 and P.I. 140467.

The IR-1 Potato Introduction Project reported the release of 'Chieftain' for commercial production. One hundred of the 106 potato varieties developed and released in the United States during the past 30 years have two or more foreign introductions in their pedigrees. Segments of the Solanum species collection were screened in Iowa and Minnesota for insect resistance.

The Minnesota Agricultural Experiment Station published, as Technical Bulletin No. 253, the results of an extensive survey for aphid resistance in 395 introductions of tuber-bearing Solanum species. New sources of resistant genes are indicated by these tests.

c. Ornamentals. At Glenn Dale an outstanding seedling from the cross P.I. 228187 Camellia rusticana 'Yoshida' X P.I. 226756 C. lutchuensis has been named 'Fragrant Pink' and released for propagation. The most outstanding characteristic of 'Fragrant Pink' is its pleasant fragrance, identical to that of the male parent. The flowers are deep purplish pink, semi-double, and about 2 1/4 inches in diameter.

From a population of 354 seedlings of the cross Ilex cornuta X I. ciliostinosa, three individuals (2 females and 1 male) were selected for propagation and further testing. The reciprocal cross has not produced any outstanding individuals.

At the Miami station, the 'Rose mound' Dombeya has performed outstandingly as a flowering shrub for landscape use and growing in containers. The clone has been propagated and distributed for wider testing.

Preparations are being made at Savannah to expand investigations with ornamental plant introductions for the lower Atlantic and Gulf Coast areas. Also at Savannah, propagation tests with rhizomes of Phyllostachys viridis, dug at monthly intervals, revealed that late February is the best time to transplant this temperate bamboo.

As a result of the exploration trip to Korea by E. G. Corbett and R. W. Lighty during 1966, many new ornamental plant introductions were received. As soon as the introductions can be propagated they will be offered to cooperators for testing in the various climatic zones of the country.

#### PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

##### Plant Introduction

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New Crop Evaluation

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SEED CROP CULTURE AND MANAGEMENT, PHYSIOLOGY AND  
BIOCHEMISTRY, DISEASES, AND QUALITY AND VARIETY EVALUATION

## Crops Research Division, ARS

Problem. Normal vegetable seed supply is adequate, but geographic concentration of the industry is potentially hazardous and problems of hybrid seed production are becoming economically serious to both the seed and vegetable processing industries. Mechanization of the vegetable industry requires increase of speed and uniformity of seedling development, but improvements in processing quality of vegetables often decrease seed quality. There is insufficient basic knowledge of physiology of seed development and germination as these influence the crop-producing potential of seeds and potential industry mechanization.

## USDA AND COOPERATIVE PROGRAM

The Department has a basic research program on the physiology and biochemistry of vegetable seed production, seed germination, and seedling vigor at Fort Collins, Colo., in cooperation with Colorado State University. Vegetable seed research is conducted in a PL 480 project in Israel on sub-microscopic changes in developing and germinating lima bean seeds. Research on plant and seed multiplication in Vietnam has been initiated through funds provided by AID.

The Federal research in this area totals 14.5 scientist man-years. Of this number 6.5 are devoted to culture and management, 1.0 to diseases, 1.9 to quality and variety evaluation, and 5.1 to physiology and biochemistry.

The Vietnam staff consists of 11.0 scientist man-years, namely, a project leader, 7 scientists, and 4 seed production advisers.

## PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 20.0 scientist man-years.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Culture and Management

Onion seed production. Yields of hybrid onion seeds have been so low and variable that continuation of hybrid seed production is threatened. Causes of low yields are unknown. Workers at Fort Collins, Colorado, collected developing umbels from commercial fields in southwestern Idaho. By separating

florets into developmental classes, losses due to "abnormal" florets were found to be 20 to 48% higher in hybrids than in an open-pollinated variety. An additional loss, 6 to 32% higher in hybrids, resulted from failure of seed development within "normal" ovaries.

#### B. Physiology and Biochemistry

Temperature sensitivity and development of bean seeds. Earlier work at Fort Collins, Colorado, had shown that the imbibition period of bean germination is especially sensitive to low temperature injury. In the case of lima beans, allowing either excised embryonic axes or whole seeds to take up water vapor until the seed moisture is about 30% eliminates temperature sensitivity. Preliminary evidence with snap beans suggests that raising the seed moisture may also increase early seedling growth. Studies of the development of lima bean seed have shown that the ability of excised embryonic axes to survive desiccation appears just prior to seed maturity. Experiments, done cooperatively with PL 480 work in Israel, have related the ability of embryonic axes to withstand drying to other features of seed development.

Submicroscopic cellular changes in developing bean seeds. In a PL 480 project at Jerusalem, Israel, scientists found that cells contain many ribosomes combined into "polysomes" until the seeds approach maturity; at that time the ribosomes appear as single units. This change in cell structure appears closely related in time to the developing ability of the cells to withstand desiccation.

#### PUBLICATIONS--USDA AND COOPERATIVE PROGRAM

None

## TROPICAL AND SUBARCTIC RESEARCH PROGRAMS

## Crops Research Division, ARS

Problem. Climatic extremes play an important part and present both problems and opportunities for agricultural research in the tropical and subarctic regions of the United States of America. Facilities provided in these locations, distant from the centers of research in the temperate zone, are utilized not only on indigenous problems but to complement, expand, and accelerate investigations in the temperate zone.

The problems are particularly aggravated by two conditions. These are the relative sparcity of agricultural knowledge, and the lack of a highly organized agriculture such as prevails throughout the temperate zone.

## USDA AND COOPERATIVE PROGRAM

Programs in this area include both basic and applied studies in a number of broad and diverse fields of agriculture. Program headquarters are located in Palmer, Alaska, and Mayaguez, Puerto Rico. Both are under, or are coordinated by the Crops Research Division.

In Alaska the research disciplines comprise soil and water utilization, crops research, plant diseases, entomology, marketing, management, economics, machinery, structures, material handling, and animal husbandry. Cooperation is effected with the Alaska Crop Reporting Service, the Alaska Division of Agriculture, Alaska's Cooperative Extension Service, and Soil Conservation Service, Matanuska Maid, Incorporated (the local farm cooperative) and other food wholesalers and retailers, U.S. Geological Survey, U.S. Weather Bureau, the North Central Region (of the experiment station's organization), various Canadian Experiment Stations, and the Matanuska Valley Breeders Association.

The Federal Experiment Station in Mayaguez, Puerto Rico, serves as the tropical research center for the Agricultural Research Service. The station conducts research with tropical plants of importance to the United States, and serves as a center for acquiring and evaluating new plant material of potential value in United States agriculture. The tropical location provides facilities for large-scale winter season testing of new breeding lines and varieties, and permits rapid seed increase of new genotypes developed at plant breeding stations in the United States. Through these procedures a tropical environment is used to reinforce and extend Departmental research programs in the United States. In some types of investigations such as sorghum breeding and selection, and screening breeding lines or varieties for disease resistance, this tropical research facility, in conjunction with Departmental activities in the States, permits completion of work in each calendar year which would otherwise require two years.

Investigations with sorghum, tobacco, sugarcane, soybeans, cereals, and Dioscorea are cooperative with Departmental research units located in the U.S. Contributed funds from industrial sources support vanilla, cacao, and black pepper investigations. The Mayaguez station cooperates closely with the Agricultural Experiment Station of the University of Puerto Rico in conducting research for development of drug, insecticidal, spice, and other specialty crops of interest to agriculture in P.R. In addition to Crops Research Division activities, the Soil and Water Conservation Service also has offices at the Federal Experiment Station in Mayaguez.

The Federal scientific effort devoted to the programs of tropical and subarctic research totals 14.9 scientist man-years.

In Alaska, 8.4 scientist man-years were devoted to subarctic research in: soil and water utilization 1.9; crops research 2.9; plant diseases 0.7; entomology 0.6; marketing, management, and economics 0.7; and animal husbandry 1.6.

In Puerto Rico, the tropical research program utilized 6.5 scientist man-years, distributed as follows: insecticidal crops 1.1; drug crops 1.1; plant introduction, distribution, and testing 0.8; spice and cereal crops 1.0; plant diseases 1.7; winter-season breeding and seed-increase 0.8.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 123.9 scientist man-years.

#### PROGRESS--USDA AND COOPERATIVE PROGRAMS

##### Crops

Vegetables. Among existing lines of commercial freezing peas, Dwarf Early Frosty is well adapted to Alaska. Sprite, Early Freezer, and several others are also adapted. Field plot studies have yielded shelled peas at the rate of 5,000 lbs. per acre. Alaska Frostless, a potato variety developed from an Alaska breeding program, was named and released in early 1967. It is intended for home gardeners in remote villages where light mid-season frosts pose a hazard; foliage of this variety has survived prolonged field frosts in which the leaves are stiffly frozen.

Supplemental water improved early and total vegetable yields; irrigation doubled lettuce and celery yields and made the difference between marketable and no cauliflower and carrot crop.

Small Fruits. An investigation of what causes winter damage to Fragaria field plantings in Alaska's Tanana Valley has pointed to low temperature pathogens rather than freezing of crown tissues. Examination of pathogens has led to isolation of a low-temperature yeast.

Plant Diseases. Green Mountain, Alaska's most popular tablestock potato, is totally infected with virus-X. A 3-year study focused on selecting less virulantly infected lines promises improved production efficiency. Tubers producing fewer spots on inoculated Gomphrena leaves yielded more potatoes the following year than those which gave many spots. Reduction in virulence is passed on to progeny tubers, the improvement being accumulatively transmitted from generation to generation. Cultures of virus-X have been maintained for 3 years in Nicotiana plants periodically pruned. Partially purified antiserum extracts from these plants are practical in field diagnosis. During the 1966 growing season 2,200 Kennebec plants from virus-X-free lines were tested by 2 people in 3 days.

Potato skin spot is believed to have been introduced into Alaska in infected tubers of the Swedish Mandel variety. Since 1964 reports of severe development in stored potatoes have grown more frequent. No effective preventive practices have yet been found.

Plant Introduction, Distribution, and Testing. The permanent cacao collection was increased by addition of new clones from various countries. The collection now contains 163 clones established in field plantings and 58 additional clones recently established in isolation greenhouses for virus indexing.

The search for new systems of cytoplasmic male sterility in Lycopersicon esculentum has been impeded by the strong unilateral incompatibility of the bridge species, L. hirsutum, now carrying S. pennellii cytoplasm, when crossed as male to L. esculentum. Although this barrier can probably be broken, some first steps have been taken to avoid the problem with an "inverted" system, in which the same genetic elements are present, but are combined in an unconventional way.

Three different mechanisms have been identified which impede reproduction of the sweet potato. In some crosses studied, embryo abortion after fertilization is an effective reproductive barrier, in addition to pollen germination failure on the stigma, and failure of pollen tubes to enter stylar tissue. In studies with other Ipomoea species four incompatibility groups were found in I. setifera and five in I. acuminata.

A cooperative sweet potato program was continued, in which plants from Tifton, Georgia, were grown to maturity for seed production in the winter season. Seeds produced in Puerto Rico were returned to the States for use in variety development programs at various locations.

Spice and Special Crops. Vanilla planifolia introductions from Mexico which were not infected when inoculated with Fusarium oxysporum in the greenhouse, were moved to field plantings for further disease resistance studies. Some plants classified as resistant in the preliminary tests immediately developed infections under field conditions. However, many remain uninfected in a field location where the disease organism is prevalent. These results suggest that this group of plants includes some which are resistant to the Fusarium organism.

Procedures were improved for inducing parthenocarpic fruit set of vanilla fruits. Repeated hormone applications have proved necessary to achieve maximum fruit development. Spray treatments with aqueous solutions were less satisfactory than treatments using lanolin paste as a carrier. Preliminary tests indicate that parthenocarpic fruits cure satisfactorily by conventional methods and that they possess the aromatic components found in seed-bearing fruits.

In a field experiment, black pepper failed to grow satisfactorily on rootstocks of Piper scabrum, P. trelesianum, and P. aduncum. Although these scion/stock combinations grow well in the protected environment of greenhouses, none proved vigorous under outdoor conditions. Several black pepper plants have been located which have survived for many years without showing any symptoms of Phytophthora root disease. These have been established for evaluation under controlled conditions.

A winter planting of 53 tomato breeding lines was grown for selection of  $F_2$  and  $F_3$  seeds. Selections from the plantings in Puerto Rico were sent to Beltsville for use in the summer breeding program.

From a winter planting of 49 cantaloupe breeding lines selections were made for local use and for use in further breeding investigations at Beltsville. Several selections which showed highest leaf disease resistance have been replanted at Mayaguez for further selection.

#### PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

##### Alaska

##### Soil and Water Utilization

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Crops Research

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## WEED CONTROL

Crops Research Division, ARS

Problem. In spite of the best efforts to control weeds, today they still constitute one of the major items in the production costs in food, feed, and fiber crops. Weeds reduce crop yields, efficiency of land uses, crop and livestock quality, effectiveness of water management, and gross losses in human efficiency. Cost of controlling weeds and losses from failing to control them are borne directly or indirectly by all facets of private and personal life. Many species of weeds are poisonous to humanity, domestic animals, and wildlife. Weeds produce toxins and allergy-causing pollens which result in an annual loss of 333 thousand work days, 3.7 million days of restricted activity, and 1/2 million days spent in bed. The annual national loss in agriculture production due to weeds and the cost of weed control is estimated as high as 5 billion dollars. These are among the most serious problems facing the agricultural economy.

The problem of herbicide residues that result from treating crops or the soil in a previous season causing damage or occurrence in a second crop in a rotation with a treated one is becoming increasingly serious. Current information is not adequate to develop herbicide-crop rotations that prevent the accumulation of herbicide residues in soils and prevent recurrence of residues in food and water.

The introduction of new and powerful chemical tools and the prospect of broader utilization of biological control agents open new horizons for productive research designed to solve our nation's weed problems.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied studies directed toward the solution of weed problems on farms, irrigation canals, ponds, rights-of-way, and other areas where weeds and brush are problems. Research on reducing damage to crops by weeds includes studies of the life histories and growth patterns of individual weeds and the use of cultural methods, biological agents, and herbicides for their control. Weed research includes physiological and biochemical studies to determine the mechanisms involved in absorption and translocation, the mode and site of action and the effect of environment on plant responses to herbicides. Comprehensive studies are made to develop principles, practices, and methods of using herbicides and other weed control techniques in solving regional agricultural weed and brush problems in agronomic crops, horticultural crops, grazing lands, and aquatic and noncropland sites.

Inhouse weed research is being conducted by the Department at 38 different locations in 27 States and Puerto Rico. All of this research is conducted cooperatively with State Agricultural Experiment Stations with the exception of the research at Beltsville, Maryland; Denver, Colorado; and Mayaguez, Puerto Rico. There is also cooperation with other Federal agencies, including the Bureau of Reclamation and Bureau of Land Management, Department of the Interior; U.S. Army Corps of Engineers; Biological Laboratories, Ft. Detrick; and Advanced Research Projects Agency, Department of Defense; and Plant Pest Control Division, and Forest Service of the Department of Agriculture, which ranges from informal exchange of information to formal arrangements providing funds and personnel in support of weed control research. Industrial companies cooperate in furnishing experimental chemicals, equipment, and funds essential to rapid progress in weed control investigations. Certain private, semipublic, or public groups, including the Central and Southern Florida Flood Control District, and the California Department of Water Resources, furnish financial support for cooperative research on weed problems.

The total Federal scientific effort devoted to weed control research is 83.2 scientist man-years. Of the total 5.0 man-years are devoted to horticultural crops.

The extramural program includes 9.0 scientist man-years supported by contributed funds and 15.6 scientist man-years in contracts, grants, and cooperative agreements with other institutions.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 143.3 scientist man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### 1. Vegetable Crops

###### a. General

Herbicide Residues in Vegetable/Cotton Rotations. Herbicides used to control weeds in cotton plantings often leave residues in the soil that cause injury to vegetable crops grown in rotation. Studies conducted at Weslaco, Texas, showed that preplanting applications of DCPA, diuron, 2,4-Bis(isopropylamino)-6-methylmercapto-*s*-triazine [prometryne], and trifluralin that were incorporated into a sandy clay loam controlled Amaranthus and barnyardgrass in cotton plantings, but persisted 7 months and injured one or more vegetable crops planted in the treated soil areas. Onions were injured by all herbicides, spinach by diuron, and carrots by trifluralin.

Effects of Herbicide Treatments on Quality and Composition of Food Crops.

Research to determine the effects of herbicide treatments on the yield and the fresh and processed quality and composition of potatoes and tomatoes is in progress under a research contract at the Ohio State University at Columbus, Ohio. Field plantings of potatoes were treated with DCPA, amiben, N,N-dimethyl-2,2-diphenylacetamide [diphenamid], and 4,6-dinitro-o-sec-butylphenol [DNBP]. Field tomato plantings were treated with DCPA, amiben, and diphenamid. Significant changes in yield or quality have not been found in two years of studies using the same varieties and treatments on the same soil.

b. Asparagus. There have been some indications that continued use of 3-(p-chlorophenyl)-1,1-dimethylurea [monuron] herbicide in commercial asparagus fields in New Jersey has caused reductions in vigor of the plantings. In studies searching for alternate herbicides for asparagus at New Brunswick, New Jersey, the herbicides 2-chloro-4,6-bis(ethylamino)-s-triazine [simazine], 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea [linuron], DCPA, and 3-tert-butyl-5-chloro-6-methyluracil [terbacil] have shown outstanding promise. Terbacil effectively controlled horsenettle, a very serious pest, and many other weeds throughout the growing season.

c. Cantaloupe. In a search for improved weed control methods for cantaloupe plantings at Weslaco, Texas, the herbicide N-butyl-N-ethyl-alpha, alpha, alpha-trifluoro-2,6-dinitro-p-toluidine [benefin] was outstanding in controlling germinating weedgrasses and broadleaf weeds and did not injure the crop. Research on benefin will continue.

Black polyethylene film used as a nonchemical method of controlling weeds in cantaloupes was an effective mulch that controlled weeds, conserved moisture, and had a stabilizing effect on soil temperatures.

d. Carrots. Among several herbicides investigated for control of weeds in carrot plantings at Weslaco, Texas, trifluralin and linuron were outstanding in performance as treatments applied to the soil before emergence of weeds. These herbicides performed effectively over a broad soil temperature range of 64 to 94° F.

e. Lettuce. In research at Weslaco, Texas, benefin and N-(2-mercaptopethyl)benzenesulfonamide S-(O,O-diisopropyl phosphorodithioate [bensulide] were very effective when used as preplanting treatments incorporated 3/4 inch deep in the soil in lettuce plantings on a Hidalgo sandy clay loam under cool wet conditions. Trifluralin at 1 lb/A persisted at crop-killing concentrations for 10 weeks after incorporation into the soil. Extremely heavy rains and flooding moved incorporated trifluralin down into the soil though this herbicide is considered relatively immobile because of its low water solubility.

f. Okra. In research at Beltsville, Maryland, 2-azido-4-sec-butylamino-6-methylmercapto-s-triazine was used as a preemergence treatment at 1, 2, and 4 lb/A on the soil surface in okra plantings on a Codorus silt loam. The 4 lb/A treatment controlled the annual weedgrasses and broadleaf weeds satisfactorily and yields equivalent to the handweeded control were obtained.

g. Onions. In a continuation of research on the use of N-isopropyl-2-chloroacetanilide, bensulide, CIPC, and DCPA in onion plantings on a Hidalgo sandy clay loam at Weslaco, Texas, bensulide was most effective and could be efficiently incorporated into the soil by any one of several methods. Bensulide at 4 lb/A incorporated into the soil just before planting of onions controlled redroot pigweed and barnyardgrass without injury to the crop.

h. Southern Peas. The control of nutsedge has become a severe problem in the production of southern peas. In experiments at Tifton, Georgia, S-propyl dipropylthiocarbamate [vernolate] used as a subsurface band placement in the soil after the pea plants have reached the 5- to 6-leaf stage have reduced nutsedge populations by more than 90 percent. This method may prove to be one of the most important new production practices for southern peas.

i. Sweet Corn. Experiments were continued at Beltsville, Maryland, to compare the efficiency of 2-chloro-4-ethylamino-6-isopropylamino-s-triazine [atrazine], cultivation, and handweeding used separately and in various combinations to control weeds in sweet corn. Very little rain fell during the growing season and it was found that treatments of atrazine at 3 lb/A on the soil surface severely reduced sweet corn brace root expansion and yields unless soil was cultivated over the brace root area. This suggests that cultivation to cover the brace roots should be a recommended practice when using surface treatments of atrazine in sweet corn plantings.

j. Sweet Potatoes. Due to the slow rate of growth during the first 6 weeks after planting, sweet potato plants are very poor competitors with the rapid growth of large populations of weeds. In experiments on a Freehold sandy loam at New Brunswick, New Jersey, amiben at 4 lb/A or trifluralin at 1-1/2 lb/A used as posttransplanting treatments effectively controlled weeds in sweet potato plantings and did not injure the crop. Preplanting treatments of trifluralin at 1-1/2 lb/A incorporated into the soil killed the crop.

k. Tomatoes. In research at Weslaco, Texas, diphenamid and bensulide used as preplanting treatments incorporated into the soil in furrow-irrigated tomato plantings on a Hidalgo sandy clay loam gave long-term control of Amaranthus spp. and barnyardgrass without injuring the tomato plants. These herbicides were effective even when temperatures were low and rainfall was high.

1. Vegetable Leaf Crops. Eight herbicides were studied alone and in combinations as preemergence treatments on mustard and turnip green plantings at Tifton, Georgia. DCPA at 4 and 8 lb/A were the best treatments overall when both crops were considered.

m. Watermelons. Preliminary experiments were initiated at Weslaco, Texas, to determine the feasibility of adapting herbicide treatments and methods of application used in cantaloupe plantings to watermelon plantings in Texas. The most promising treatments under heavy rainfall conditions were trifluralin at 3/4 lb/A, bensulide at 8 lb/A, and CDEC at 6 lb/A applied on the soil and incorporated immediately after planting the watermelon seed. Treatments of DCPA or N-1-naphthylphthalamic acid [NPA] at 8 lb/A caused severe injury.

## 2. Fruit Crops

a. Apples. In long-term studies of herbicide use in apple orchards at New Brunswick, New Jersey, diuron at 2 lb/A, simazine at 4 and 8 lb/A, CIPC at 6 lb/A, diuron at 2 lb/A plus CIPC at 6 lb/A, and 3-amino-1,2,4-triazole [amitrole] at 6 lb/A spring and fall, used annually for 6 years for control of germinating weeds did not cause reductions in growth, yield, or quality of the crop. Excellent weed control was obtained with diuron at 4 lb/A, simazine at 8 lb/A, and diuron at 2 lb/A plus CIPC at 6 lb/A. The other treatments were not satisfactory. Plots treated with plastic mulch, the plots treated with ineffective herbicides, and the control plots infested with weeds suffered moderate to severe mouse damage, a factor which varies with density of vegetative or other cover of the soil.

New research was initiated in 1965 on the use of azide, simazine, simazine plus 2-tert-butylamino-4-ethylamino-6-methylthio-s-triazine [GS-14260], simazine plus oil, 1,1'-dimethyl-4,4'-bipyridinium salt [paraquat], terbacil, 5-bromo-3-tert-butyl-6-methyluracil, and amitrole herbicides as directed sprays to control established weeds. Simazine gave excellent weed control and the addition of either 2-tert-butylamino-4-ethylamino-6-methylthio-s-triazine or oil increased the level of control. The longest periods of weed control were obtained with simazine plus oil and terbacil plus 5-bromo-3-tert-butyl-6-methyluracil. Paraquat looks very promising for control of growing vegetation.

b. Blueberries. Disking and rotary hoeing are used to control weeds in blueberry plantings. Severe root pruning and barking injury from these methods have been observed and the weeds near the blueberry plants cannot be satisfactorily controlled in this way. Effective, safe herbicides for

blueberry plantings are being sought in research at New Brunswick, New Jersey. Simazine and diuron have been used annually for 7 years on a blueberry planting without causing injury to the crop when used at minimum levels that control weeds. Somewhat higher rates of diuron significantly reduced berry size and caused some injury symptoms on the foliage of the blueberries. Quality of the crop was not affected by minimum effective herbicidal treatments. This research is being continued and will include analyses to determine if herbicide residues have accumulated in the soil as a result of the treatment.

c. Cranberries. Two of the 3 leading States in the production of cranberries are in the Northeast. Weeds are now the greatest problem confronting the growers in the culture of cranberries. Research to develop methods for chemically controlling weeds in cranberry plantings is continuing at New Brunswick, New Jersey. A new bog was established and herbicide treatments will be made in the spring of 1967.

d. Grapes. Grape plantings were established for weed research in 1963 at New Brunswick, New Jersey. Herbicide treatments were begun in the spring of 1964 in a long-term study of the effects of repeated treatments. Simazine at 2 and 4 lb/A, diuron at 2 and 4 lb/A, dichlobenil at 8 lb/A, DCPA at 8 lb/A, diphenamid at 2 and 8 lb/A, linuron at 1 and 2 lb/A, amiben at 2 and 4 lb/A, vernolate at 4 lb/A, terbacil at 4 lb/A, and paraquat at 2 lb/A were used to kill germinating weeds. Excellent weed control was obtained with all treatments except linuron at 1 lb/A. There were no visible symptoms of injury to the crop from any of the treatments. First yields and quality evaluations will be made in 1967.

e. Peaches. An initial experiment on the effects of long-term use of herbicides in peach plantings at New Brunswick, New Jersey, was begun in 1960 and will be continued through 1967. Treatments were diuron at 2 lb/A, simazine at 2 and 4 lb/A, CIPC at 6 lb/A, diuron at 1 lb/A plus CIPC at 6 lb/A, dalapon at 6 lb/A in the spring plus 6 lb/A in the fall, black polyethylene mulch, clean cultivation, and weedy control which was periodically mowed. All treatments except CIPC and dalapon alone gave excellent weed control. Highest yields were obtained in the plots treated with simazine at 2 lb/A, black polyethylene mulch, and clean cultivation in relative order as listed. None of the treatments caused any visible injury symptoms to the crop. Trunk measurements have been taken and the data will be analyzed to determine effects of treatments on trunk expansion. Leaf samples have been collected for analysis for N, P, and K. Soil samples will be analyzed for herbicide residues in each plot. The study will be terminated in 1967 and a final evaluation made of the results.

New peach plantings have been made at New Brunswick, New Jersey, on which a number of other herbicides will be used on a long-term basis.

3. Ornamentals

a. Gladiolus. Research on weed control in gladiolus plantings at New Brunswick, New Jersey, in a Freehold sandy loam involved the use of monuron, amiben, trifluralin, linuron, simazine, vernolate, and dichlobenil herbicide treatments compared with flaming and handweeding. Vernolate herbicide treatments and flaming reduced the number of flower spikes, and the weight of flowers and corms in plantings made in 1966 with cormels from the 1965 experimental treatments. Gladiolus in plots that were flamed were generally less vigorous than handweeded plots, indicating that gladiolus is a very poor competitor with weeds as indicated by the fact that the only exposure to weed competition was during the first two weeks after emergence of the crop. Good to excellent weed control was obtained with all of the herbicide treatments and with flaming.

b. Yew and Japanese Maple. Studies on the repeated annual use of herbicides on yew and Japanese maple at Beltsville, Maryland, begun in 1964, have been terminated. Herbicides used in these studies on a Codorus silt loam were DCPA, diuron, simazine, CIPC, sodium 2,4-dichlorophenoxyethyl sulfate [sesone], amitrole, and trifluralin. Herbicides were applied at normal, twice normal, and four times normal rates to evaluate their selectivity on these species. DCPA and CIPC effectively controlled annual weedgrasses. The other herbicides controlled annual weedgrasses and broadleaf weeds. Diuron caused severe injury to the crops when rates were raised above normal. It is felt that use of different herbicides in alternate years could possibly reduce injurious effects. Several of these chemicals, including DCPA, CIPC, amitrole, and trifluralin, appear safe for use in these crops and should give effective weed control when used alone or in combination. Additional research on holly and dogwood has been initiated at Beltsville, Maryland.

## PUBLICATIONS--USDA AND COOPERATIVE PROGRAM

Vegetable Crops

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Fruit Crops

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Ornamentals

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## NEMATODE IDENTIFICATION, BIOLOGY, AND CONTROL

## Crops Research Division, ARS

Problem. Nematodes attack all crop plants, but cause varying damage and crop losses, depending on the nematode, crop, and environmental conditions. Most plant-parasitic nematodes infect roots and other underground parts of plants, but some attack bulbs, stems, leaves and flowers. Damage initiated by nematodes is often extended by bacteria, fungi, and viruses. Damage can be reduced by use of varieties resistant to nematodes, but only a relatively few are available. Development of resistant varieties is a time-consuming task and does not completely protect the crop because multiple nematode resistance is difficult to attain and is lacking in all varieties thus far developed. Crop rotations have been devised to reduce some of our more important nematode problems, but rotations rarely fit modern management practices, or maybe uneconomical. While naturally-occurring biological agents undoubtedly have a great influence on nematode populations, manipulation and use of these principles for economic control is not yet practical. Great advances have been made in chemical control, but use of nematocides on many crops is not economically feasible. More effective and cheaper nematocides, and improved methods of application are needed.

## USDA AND COOPERATIVE PROGRAM

The Department has a long-term, continuing program of basic and applied research on various phases of nematology. In the past few years, as State nematology programs have developed, there has been increased emphasis on basic research in the Department's program. Fundamental research on nematode taxonomy, pathology, ecology, and physiology is located at Beltsville, Maryland. In addition, 15 field stations combine applied and basic research approaches to solve nematode problems on various crops. Research on nematodes affecting citrus is located at Phoenix, Arizona; Orlando, Florida; and Weslaco, Texas; on deciduous fruits and tree nuts at Tifton and Byron, Georgia, and Logan, Utah; on vegetable crops at Tifton, Georgia; Weslaco, Texas; Charleston, South Carolina; Salinas, California, and Baton Rouge, Louisiana; and on ornamentals at Tifton, Georgia, and Orlando, Florida. The work at all field stations, except in Florida and South Carolina, is in cooperation with the respective State Agricultural Experiment Stations.

Extramural Research is in progress at several Universities.

PL 480 projects are as follows: at Poznan, Poland, on the nature of resistance to nematodes; at Skiernewice, Poland, on nematodes attacking strawberries, carrots, and cabbage; at LaMolina, Peru, for research on the golden nematode of potatoes; at Aligarh, India, for nematodes attacking vegetables; at Anand and Pantnagar, India, on nonchemical methods of controlling nematodes; at Aurangabad, India, on distribution and pathogenicity of nematodes in Maharashtra; and at Rehovot, Israel, on nematodes as vectors of diseases on citrus and other fruit crops.

The Federal Intramural Program devoted to nematology research totaled 26.0 scientist man-years. Of this 7.8 were devoted to basic research on nematodes; 1.8 to research on citrus; 0.5 to deciduous fruit; 2.6 to vegetables; and 1.8 to flowers and ornamentals.

The Federal Extramural Program devoted to nematology research in FY 1966 totaled 5.0 scientist man-years. Of this 3.0 were devoted to basic research on nematodes.

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 47.3 professional man-years is devoted to this area of research.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### 1. Fruit Crops.

a. Citrus. Estimates of citrus losses in Florida to the citrus nematode (Tylenchulus semipenetrans) show that 50% of the 800,000 acres of citrus in Florida are infested with this nematode, and losses of 9,800,000 boxes of fruit valued at \$10,000,000 occur annually. Greenhouse studies in Florida indicate that the burrowing nematode can move across a fallow barrier at the rate of about 8 inches a month when weeds grow in the barrier, indicating that control areas must be kept free of all weeds at all times. Seasonal population changes of the citrus nematode show high peak populations in Florida in April-June and October-November, when root flushes occur; populations are lowest between January-March, indicating that soil fumigation for nematode control will be most successful during this early spring period when populations are normally lowest. In Arizona, a nine-year study of citrus nematode control with a commonly used halogenated hydrocarbon in irrigation water continues to show that citrus groves treated with two gallons per acre of this material, allows normal citrus growth and gives good nematode control for two years. Then retreatment is necessary. Nematode control and good citrus growth and fruit yield is maintained for three years at a 4-gallon dosage and for five years at a 6-gallon dosage. The lower dosages appear most practical.

b. Peaches. In January 1966, nematology research was initiated at Byron, Georgia, on the peach replant and decline problem, which threatens the peach industry of the Southeast. Root-knot (Meloidogyne spp.) and root-lesion (Pratylenchus spp.) nematodes are considered serious pests of peaches, but the role of these and other nematodes in the replant and decline problem has not been convincingly established. In 1966, three species of root-lesion nematodes (Pratylenchus brachyurus, P. zeae, and P. vulnus) were found commonly on peaches in central Georgia. P. vulnus, which has been associated with peach decline in California, was found for the first time in Georgia. It was the only species of this genus that was constantly associated with peach decline in Georgia. A striking correlation was found in comparison of trees with different vigor; the less vigorous trees had large populations of P. vulnus (as many as 1,000 nematodes per gram of root), while vigorously growing and apparently healthy trees had very low populations. Preliminary studies indicate that of the six proprietary nematocides evaluated for nematode control on peaches, Temik gives best nematode control and tree response the first year after treatment. These studies will be continued for at least five years.

2. Vegetables and Potatoes. In Louisiana, 13 proprietary and experimental nematocides were evaluated on sweetpotatoes; best reniform nematode control and yield increases (72-113 bushels of US #1) were given by two organophosphates, an oxime, a halogenated hydrocarbon, and a mixture of a halogenated hydrocarbon. Chemical control of sting, root-lesion, stubby-root, and dagger nematodes in field plots in Georgia on sweet corn, okra, lima beans, and southern peas gave yield increases of 165, 214, 49, and 173 percent, respectively, for the best nematocide treatment (an organophosphate). The oxime rated second in this test, followed by standard proprietary nematocides. Progress is being made at Charleston, South Carolina, to develop root-knot resistant cantalopes, bush beans, Jackson Wonder type lima beans, watermelons, tomatoes, and sweetpotatoes. Backcrosses (F<sub>4</sub> and F<sub>5</sub>) of bush bean and lima bean lines are particularly promising. Four hundred lines of sweetpotatoes from Tifton, Georgia, were evaluated at Charleston for susceptibility and resistance to M. incognita acrita; fifty resistant lines will be studied further.

Evaluation of nematode susceptibility has been aided, and refined, by the development of a new laboratory technique that allows observations of resistance ratings on vegetable roots 3-5 days after a nematode inoculation in clear plastic seed-germination test pouches.

3. Ornamentals. In Florida, losses to nematodes from poor growth, and quarantine, amounts to about 10 percent. Equally high damage occurs on ornamentals in other Gulf Coast States. In tests in Georgia and Florida, nematodes, were effectively controlled in container-grown plants by drench

or by bare-root dips of several ornamentals with three organophosphates and the same oxime. These chemical treatments have been so successful in ridding citrus seedlings and ornamental plants of burrowing nematodes that the Plant Pest Control Division and the Florida Department of Agriculture are in the process of accepting bare-root dips with these chemicals in lieu of the expensive preshipment site-certification for citrus nurseries. In Georgia, tractor applied sidedressings of liner grown ornamentals with the same chemicals were less effective.

#### PUBLICATIONS--USDA AND COOPERATIVE PROGRAM

##### Fruit

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##### Ornamentals

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EPIDEMIOLOGY AND MYCOLOGY OF PLANT DISEASES,  
NATURE OF PLANT RESISTANCE TO DISEASES AND INSECTS, AND MUSHROOM CULTURE

Crops Research Division, ARS

Problem. Knowledge of the causative agents of diseases, including their identification, life cycles, epidemiology, ecology, and relationship to other organisms, is fundamental for the application of disease prevention and control methods. There is urgent need for broader taxonomic coverage of the fungi to provide authoritative identification of plant pathogens. Basic research is needed on their characteristics and classification. We require additional information on the factors involved in epidemic outbreaks to develop effective disease forecast methods that will facilitate prevention and control programs.

Soilborne pathogens cause some of the most destructive plant diseases. The causal organisms usually have wide host ranges and survive in soil for long periods. For many, control by resistant varieties or fungicides has not proved feasible. Biological controls are our strongest hope for controlling these diseases. Effective and economic biological control depends on a strong research program aimed at understanding the intricate interactions and associations among plants, pathogens, and the physiochemical and biological environment of the soil.

To develop better strains of mushrooms, increase yields, and improve flavor, basic studies are needed to understand the nutrition of cultivated mushrooms, to control diseases and insects economically and adequately, to permit the identification and selection of "marker" characters to be used in genetic studies, and to provide badly needed genetic information to start a breeding program.

The development of plants resistant to disease organisms and insects is hampered by ignorance of the basic nature of resistance. An understanding of why an insect or pathogen attacks one plant and not another could be used by crop scientists in developing resistant varieties. The availability of more resistant plants would reduce the losses caused by these pests, reduce the need for pesticides, decrease cost of production, and lower the cost of food. Information obtained from this research program will also aid in the development of non-pesticide control measures and better approaches to the development of specific and safer pesticides.

USDA AND COOPERATIVE PROGRAM

The Department research is conducted at four locations. Identifications of plant pathogens and other fungi are made and the National Fungus Collections are maintained at Beltsville, Maryland. Research on the epidemiology of potato and tomato late blight, bacterial spot of pepper and tomato, lima bean downy mildew, brown spot of tobacco, and yellow dwarf virus of small grains provides improved bases for forecasting.

Research is conducted in cooperation with the State Agricultural Experiment Stations at Raleigh, N. C.; Ames, Iowa; and University Park, Pennsylvania. Unusual records of disease occurrence, new controls, and new research and control techniques are published monthly in the "Plant Disease Reporter." Research on biological control of soilborne plant pathogens and on nutritional and other environmental factors affecting growth, quality, and yields of mushrooms is also conducted at Beltsville. A multidiscipline team has initiated research at Beltsville on the physiological, biochemical, morphological and other factors responsible for the resistance of plants to disease and insect attack. Cooperation will be informal with appropriate Branches of the Crops and Entomology Research Divisions. Close liaison will be maintained with the Crops Research Division's Pioneering Laboratory on the Nature of Disease Resistance in Plants at Madison, Wisconsin.

One contract at Lincoln, Nebraska, on survival of some important soilborne plant pathogens in the midwest, one grant at Madison, Wisconsin, on biological and physiochemical factors affecting survival of Aphanomyces euteiches, and a second grant at Berkeley, California, on variation, survival, and virulence of Rhizoctonia solani are in effect. A research contract entitled "Biochemistry of host-plant preference in Agasicles sp. (Coleoptera: Chrysomelidae) to alligator weed" was initiated by Stanford Research Institute.

Nine PL 480 projects are in effect. One in Pakistan and four in India relate to the occurrence and distribution of fungi; one in India with the distribution of plant pathogens in the air over cane fields; one in Israel with the epidemiology and forecasting of downy mildews and related pathogens in an arid climate; and one in India and another in Israel with soil organisms and biological control of plant diseases.

The Federal Intramural Program devoted to research in this area totals 22.3 Scientist Man-Years divided as follows: Identification and classification 6.0, epidemiology 3.5, biological control of soilborne diseases 8.3, mushrooms 2.0, and nature of plant resistance to diseases and insects 2.5.

The Extramural Program for this area totals 1.5 SMY divided as follows: Identification and classification 0.1, biological control of soilborne diseases 1.3, and nature of plant resistance to diseases and insects 0.1.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Current research at State Agricultural Experiment Stations amounts to 28.0 SMY.

## PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Epidemiology

1. Downy mildew of lima bean. *Phytophthora phaseoli* formed most sporangia within 3 days on established lesions in dew cabinets at 15°, 20°, or 25°C. More than 80 percent of the total number were formed on the first day. On plants exposed to the same light intensity for different daily periods of time during colonization a significantly greater number of sporangia developed within 16 hours as compared with 12 hours of light. Maximum colonization and much sporulation occurred under a fluctuating temperature regime of 20°/15°. The maximum rate of colonization and most sporulation (both rate and quantity) occurred at 27°/22°. Infection has been obtained from sporangia stored at -60°C for one year.
2. Bacterial spot of pepper and tomato. In 17-row plots of pepper plants, every 11th plant in row 9 was inoculated with *Xanthomonas vesicatoria* at transplanting time. By mid-August infection had spread to 2 or 3 plants within the row and to 1 row on each side of the inoculated row. By October 21 infection was general with moderate severity and some defoliation. Infection was about as severe on plants at margins of plots as on those next to inoculated plants. Yield reduction was 30 to 40 percent.
3. A PL 480 project in Israel on the epidemiology and forecasting of downy mildews and allied fungi in an arid climate with and without the aid of irrigation was continued. A portable quantitative inoculator was developed which helped to standardize inoculation procedures. Isolation of a high temperature strain of the potato blight fungus which caused severe damage in Israel fields may explain why this disease is so severe and erratic under their hot, arid conditions.

B. Biological Control of Soilborne Plant Pathogens

1. Development of a quantitative assay method for observing and enumerating propagules of root-infecting fungi at Beltsville, Maryland. A method was developed for direct assay of propagules of root-infecting fungi from soil. Soil suspensions in 0.5% carboxymethylcellulose were comminuted, spread on modified peptone-pentachloronitrobenzene (PCNB) agar, stained with lacto-fuchsin, and examined with a 25X or 40X objective. Quantitative data for *Fusarium solani* f. *phaseoli* and *F. solani* f. *pisi* obtained with this method correlated well with data obtained with the dilution plate method. Germi-nated and ungerminated propagules of *Helminthosporium sativum* and *Thielaviopsis basicola* also could be observed. The method can provide quantitative results; large soil particles and sand granules do not interfere with observations because they are pressed into the agar by the cover glass; and no special materials or equipment are needed.

2. Evaluation of various media and antimicrobial agents for isolation of *Fusarium* from soil at Beltsville, Maryland. From 18 media recommended for isolation and enumeration of *Fusarium* spp. from soil, peptone-PCNB and V-8 juice-dextrose-yeast extract agar were the most valuable with the soil dilution plate method. From several antimicrobial agents tolerated by *F. oxysporum* and *F. solani*, oxgall, PCNB, chlortetracycline HCl, and streptomycin sulfate were selected for improving the foregoing media. The modified peptone-PCNB medium is recommended for isolation and enumeration of *Fusarium* and for ease of preparation.

3. Development of a buried filter method for studying fungal behavior in soil. In this method, fungus propagules are placed on membrane filters and the filters buried in soil. After incubation under the desired environmental conditions, the filters are stained, mounted, and examined. Results agreed closely with those of in vitro experiments on the effect of temperature on endoconidial germination of *T. basicola*. This method has been used to study the germination of spores of *T. basicola* and *F. solani* in soils amended with various chemicals or natural products. By amending soils with various concentrations of glucose or other energy source and determining the degree of spore germination in the soil at each concentration, the fungistatic level of soils has been determined. When air-dried soil is moistened to 50% moisture-holding capacity, 7 to 14 days are required for the soil to become highly fungistatic against chlamydospores of *F. solani*.

4. Comparison of treatments suggested for control of *Aphanomyces* root rot of peas. Comparative studies of several treatments suggested for control of this disease showed that some methyl-containing amino acids, Dexon, and cruciferous amendments can suppress the disease in the greenhouse if properly applied to soil.

5. Chlamydospore germination of *Fusarium solani* f. *phaseoli* in natural and cellulose amended soil. Macroconidia of this fungus germinated well in control soil and soil amended with 1% cellulose. Chlamydospores germinated poorly or not at all in control and cellulose amended soils. The addition of exudates from germinating bean seeds and 0.01% glucose stimulated chlamydospore germination in control soil but not in cellulose amended soil. These results indicate that a cellulose amended soil reduces the severity of *Fusarium* root rot of bean by preventing germination of the chlamydospores. With higher concentrations of glucose (0.1 and 1.0%) cellulose was not inhibitory. Even though nitrate nitrogen has been reported to increase disease severity, it has little effect on chlamydospore germination in cellulose amended soil assayed with 0.1% glucose. As an inexpensive form of cellulose, ground newspaper at 0.2% was as effective as purified cellulose in reducing root rot of bean. Coffee grounds from instant coffee manufacturing processes also reduce this root rot.

6. Effect of tannins on spore germination and growth of *Fusarium solani* f. *phaseoli* and *Verticillium albo-atrum*. Gallotannin, wattle, canaigre, and chestnut tannins in a complete medium at the proper pH affected spore germination and mycelial growth of these two fungi. At pH 5, gallotannin, canaigre, and chestnut tannins at concentrations of 39-625 ppm inhibited spore germination of both fungi. At 1000 ppm these tannins completely prevented growth during a 20-day period. At pH 6-8 there was little inhibition of spore germination or mycelial growth with all tannins tested except gallotannin, which prevented growth of both fungi under alkaline and acid conditions.

7. Studies on the behavior of *Verticillium albo-atrum* in soil at Beltsville, Maryland. A selective medium for detection, isolation, and enumeration of this fungus from soil was improved by the addition of polygalacturonic acid and three broad-spectrum antibiotics to the dilute soil-extract medium. Addition of polygalacturonic acid increased melanization of the fungal cells and, therefore, detection of the pathogen.

Soil populations of *V. albo-atrum* can be increased or decreased by varying the carbon source, C:N ratio, or type of soil amendment.

The microsclerotia of this fungus produce chains of secondary microsclerotia in soil amended with glucose, sucrose, galactose, and other sugars. This may be an important means of inoculum increase in the rhizosphere or in other soil micro-sites. *V. albo-atrum* did not competitively colonize plant debris in soil regardless of the type of propagule introduced.

8. Studies of root exudates of peas at Beltsville, Maryland. Water-soluble carbohydrates and amino acids exuded by roots of peas grown aseptically in solution cultures were quantitatively and qualitatively determined. The amounts and kinds of amino acids and sugars released by two varieties of peas of varying resistance to infection by *Fusarium oxysporum* f. *pisi* were similar if not identical. These root exudate components are probably not responsible for the differing degree of resistance of these plants to *Fusarium* infection.

9. Survival of soilborne plant pathogens in the Midwest. These studies were made under contract at Lincoln, Nebraska. Studies to determine the source of initial inoculum of *Helminthosporium turcicum*, the cause of Northern Leaf Blight of corn, were completed. The overwintering conidia associated with residues of corn leaves, leaf sheaths and husks is the principal source of primary inoculum in Nebraska. Overwintering conidia undergo marked structural changes, principally the formation of chlamydospores within the conidia. Dessication of conidia may stimulate formation of chlamydospores within the conidia.

Survival studies of bacterial pathogens of beans were continued. Straw maintained on the soil surface for 10 months was more favorable for survival of bacteria than straw buried in the soil. Fuscous, orange wilt, and common blight bacteria, in that order, were more readily recovered than the other bacterial pathogens.

10. Studies on biological control of Aphanomyces root rot of vegetables, especially processing peas. In extramural research at Madison, Wisconsin, a laboratory technique for the assay of inoculum potential of A. euteiches was developed. Pea seedlings grown in vermiculite were placed on moist paper towels, inoculum (soil from infested fields washed through graded sieves) was applied to the roots, and the towels were rolled up. Symptoms of infection appeared within 10 days. The number of plants showing symptoms increased for about three weeks. The wet weight of inoculum per root varied from 2 to 16 mg. The number of plants infected doubled as inoculum increased to 8 mg and remained at that level with further increases in inoculum. A comparison was made of the infectivity of the residue retained by the various mesh sizes. There were fewer infectious propagules in the finer fractions.

11. A PL 480 project on the behavior and biological control of Sclerotium rolfsii and Rhizoctonia solani in Israel was continued. Hyphal and sclerotial walls of S. rolfsii were studied chemically and enzymatically. Upon acid hydrolysis, hyphal and sclerotial cell walls yielded amino acids, reducing sugars and N-acetyl glucosamine. Lipids were detected in ether extracts of both hyphal and sclerotial walls. Melanine-like pigments were found in sclerotial but not in hyphal walls. Also, sclerotial walls contained higher amounts of non-hydrolyzable residue than hyphal walls. It is suggested that melanin-like pigments and the non-hydrolyzable residue play an important role in the higher resistance of the sclerotia to chemical and biological degradation. A B-(1-3) glucanase (laminarinase) enzyme capable of lysing hyphal walls of Sclerotium rolfsii was concentrated from the supernatant of a Pseudomonas culture. No chitinase activity was detected. It appears that these walls contain both glucan and chitin. A method for the quantitative estimation of the saprophytic activity of S. rolfsii was devised in which sugar beet segments or sorghum seeds boiled in 5% glucose were used as baits for the pathogen.

#### D. Mushrooms

1. Supplementation of casing layer and spawned compost. Tests of the effects of adding different substances to the casing layer or to the compost were continued. Material high in lignin was not utilized by mushroom mycelium. Addition of activated carbon to the casing layer produced fruit

deformity when the carbon exceeded 25 g/7 lb casing soil. The addition of carbon to spawned compost halfway through the crop did not affect the subsequent yield or number of mushrooms.

2. Spore Germination. A routine procedure to provide 60-80% germination of Agaricus bisporus basidiospores was developed. Using this method, study of the effect of factors such as nutrition and variety on spore germination has been started. Results so far indicate considerable differences among the different varieties tested.

3. Effect of concentration and means of application of Zineb on the growth and yield of mushrooms. Some mushroom growers use the fungicide zineb to prevent the mushroom disease known as "bubbles." In practice such use may result in exceeding the recommended ppm especially at the most sensitive concentrations of zineb were applied at casing time. Various thicknesses of casing were employed and the zineb was "carried down" by water in various degrees. A thin casing layer and a heavy watering just after zineb application decreased the number of mushrooms harvested. The yield of mushrooms was not affected by the treatments. Further knowledge about this or similar cultural practices is important because the increase in mushroom size is desirable. "Chemical pruning" by means of this pesticide is not recommended.

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## VEGETABLE INSECTS

## Entomology Research Division, ARS

Problem. More effective, economical, and less objectionable methods of controlling insect and mite pests of vegetables in the field without leaving undesirable residues on or in the marketed product or in the soil, and without affecting the flavor or quality of the product, or adversely affecting beneficial insects, are the major objectives of this research. Insects and mites are important limiting factors in the production of high-quality vegetables. These pests reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. Use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating animal products by feeding crop refuse or byproducts of peas, beans, sweet corn, or other vegetables treated with insecticides to livestock. Drift of certain insecticides into non-target areas may also cause problems. A number of vegetable insects have developed resistance to certain insecticides. Research is needed on methods for better utilization of predators, parasites, and diseases of vegetable insects and mites; bioenvironmental and cultural methods; development and utilization of more effective traps and lures; new approaches to control including radiation, chemosterilants, and antimetabolites; evaluation of insecticide application equipment; and the practical integration of non-chemical and chemical methods in area control of vegetable insect and mite pest populations. Additional emphasis is being placed on research to develop vegetable crops resistant to insects and to determine the factors responsible for resistance when found. Research is needed on insect vectors of vegetable diseases and the role they play in the dissemination of viruses. The heavy losses caused by viruses transmitted by insects to a variety of vegetable crops emphasizes the importance of research in this field.

## USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz., Riverside, Calif., Tifton, Ga., Twin Falls, Idaho, Lafayette, Ind., Beltsville, Md., Wooster, Ohio, Forest Grove, Oreg., Charleston, S.C., and Yakima, Wash., in cooperation with the respective State experiment stations and industry. Much of the work is in cooperation with the Crops Research, Pesticides Regulation, and Agricultural Engineering Research Divisions. Work in Idaho is also cooperative with the Idaho Bean Commission and that in Maryland with the Northern Utilization Research and Development Division and the Human Nutrition Research Division. Work in Oregon is conducted jointly with the Agricultural Engineering Research Division. Research is being conducted in Indiana and Washington under a research grant to the Indiana Agricultural Experiment Station and by cooperative agreement with Walla Walla State College, respectively.

Work in Karaj, Iran, and New Delhi, India, on insects affecting vegetable legumes is supported with funds supplied by the Agency for International Development (AID) under the grain legume project in cooperation with the Crops Research Division, the Soil and Water Conservation Research Division, Karaj Agricultural College, the Iran Ministry of Agriculture, the Iran Plan Organization, Pahlavi University in Shiraz, Iran, the Indian Council for Agricultural Research, and the Indian Agricultural Research Institute.

The Federal scientific effort devoted to research in this area totals 27.1 scientific man-years. Of this number 1.7 is devoted to basic biology, physiology, and nutrition; 2.9 to insecticidal and cultural control; 3.2 to insecticide residue determination; 6.4 to biological control; 4.0 to insect sterility, attractants, and other new approaches to control; 1.8 to evaluation of equipment for insect detection and control; 5.2 to varietal evaluation for insect resistance; 0.4 to insect vectors of diseases; and 1.5 to program leadership.

In addition Federal support of research in this area under contracts and grants provides 0.8 man-years. Of this total 0.2 is devoted to biological control and 0.6 to insect sterility, attractants, and other new approaches to control.

Two projects have recently been initiated under PL 480 research grants in Israel. These include studies on periodic acquisition of tomato yellow leafcurl virus by its vector the tomato whitefly (A10-ENT-21) and on development of methods for control of the Baluchistan melon fly (A10-ENT-24). Other PL 480 research projects underway include research in India on Indian Jassidae with particular reference to Circulifer and related genera and their importance as vectors of plant virus diseases (A7-ENT-22) and on physiological factors governing susceptibility or resistance of crop plants to leafhoppers (A7-ENT-44) and in Israel on factors influencing variations in resistance of insects to insecticides (A10-ENT-13).

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 47.5 professional man-years is devoted to this area of research.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Physiology, and Nutrition

1. Southern Potato Wireworm. Conoderus falli adults constituted 99% of the elaterids caught in a 15-watt blacklight trap operated throughout 1966 in a vegetable growing area near Charleston, S.C. Eighty-five percent of the elaterid larvae in samples of cultivated soil in the area during October and November were southern potato wireworm. An average of 3.0 elaterid larvae per square foot, to 6-inch depth, were found. Of 223 potato lots inspected, 11.2% showed 1.5 to 2.9% by weight wireworm "damaged" tubers.

2. Cucumber Beetle Rearing. At Charleston, S.C., large numbers of banded cucumber beetles, spotted cucumber beetles, and striped cucumber beetles were reared in the laboratory with relatively simple equipment and at a reasonable cost.

3. Cabbage Looper. At Charleston, S.C., cabbage looper larvae were reared to pupation on a standard collard powder diet or the standard diet diluted by doubling the distilled water content. Pupae from larvae reared on the standard diet were heavier than the pupae from larvae reared on the diluted diet.

At Riverside, Calif., calcium and sodium ascorbate were satisfactory substitutes for ascorbic acid in cabbage looper larvae diets. Blending of cabbage looper larval diet after preparation in the steam kettle was found to be a necessary step in the preparation of the medium. Studies indicate that blending the wheat germ dietary component before adding it to the kettle and subsequent normal mixing in medium preparation may be an adequate substitute procedure.

4. Lygus. Weekly sweep-net surveys for lygus from August through September 1966 at Riverside, Calif., indicated highest lygus adult and nymph populations of 1.10 and 1.06 per sweep on August 17 and 9, 1966, respectively. Lowest populations were .33 adults and .13 nymphs per sweep on September 8 and August 23, respectively.

5. Pepper Weevil. Also at Riverside higher pepper weevil populations were found during mid-September to late November in pepper fields where second fruit set and blossoms were available compared to populations in fields with plants that did not fruit a second time.

Pepper weevils have been successfully reared on a modified boll weevil diet and also on a modified cabbage looper diet. More nonviable eggs were obtained from weevils reared on the looper diet, but adults were larger and emerged at least two days earlier than those reared on the boll weevil diet. Reducing the mold inhibitor content of the looper diet resulted in higher and earlier emergence and increased egg hatch. Five, four, and two generations, respectively, of weevils have been reared on boll weevil diet, cabbage looper diet, and cabbage looper diet with reduced amounts of mold inhibitors. Emergence ranged from 48 to 64%, 45 to 56%, and 60 to 69%, respectively.

6. Flea Beetle. At Beltsville, Md., tobacco flea beetle larvae in all stages of development tunneled into tomato seedling roots and the hypocotyls collapsed, followed by plant prostration. The symptoms are strikingly similar to "damping off" and may be erroneously ascribed to infection by *Rhizoctonia*, *Pythium*, or other soil fungi.

Several generations of tobacco flea beetles have been successfully reared on subirrigated potato plants grown in a fertilized peat-vermiculite mixture at 80° F, 70-80% relative humidity, and 16-hour photoperiod. Adults oviposit

on moist cheesecloth. The eggs are collected and surface sterilized in chlorinated water. Behavior and development of larvae may be easily studied by transferring the young larvae onto the roots of tomato seedlings growing in transparent Grow Pouches. Under these conditions egg to adult development is completed in 22-26 days as follows: Egg, 4-5 days; larval stage, 13-15 days; and pupal stage, 5-6 days.

7. Emoasca. At Delhi, India (A7-ENT-22) orientation studies showed that Emoasca devastans has greater preference for the hosts Gossypium hirsutum, G. herbaceum, and Solanum melongena than for G. arboreum, Ricinus communis, and S. tuberosum. Emoasca kerri motti had greatest preference for R. communis. Feeding studies showed that E. kerri motti larval weight gain as well as growth index was highest when this leafhopper was reared on R. communis and S. tuberosum. No difference in larval weight gain nor growth index was observed when E. devastans was reared on these hosts.

8. Corn Earworm. At Tifton, Ga., the casein-wheat germ diet has been replaced with a less expensive pinto bean diet for corn earworm rearing. The bean diet has been satisfactorily modified to shorten length of time required for pupation and to obtain a more uniform rate of pupation. Eggs are surface sterilized chemically, dried, removed, and then added directly to the diet, using a small hand shaker. Insects are stored until pupation, then moved to a large room for emergence. Moths are sexed as they are collected from the walls and ceiling twice daily, using hair-dryer collectors. Agricultural engineers at Tifton, Ga., in cooperation with entomologists, have developed a machine for collecting the pupae from individual cups automatically. Additional modifications are needed to make this machine fully satisfactory.

At Tifton, a detailed study of the corn earworms' antennae has revealed a minimum of 14 separate distinct types of sensors. These sensors have been plotted both with respect to the number present and to their physical configuration on the antennae of 4 different species of Noctuidae and 1 species of Pyralidae. Accurate plots of the placements of the various sensillae and their length in relation to the position they occupy on the antennae are necessary in order to define the array configurations of these antennae. Electrophysiological work has shown that the scape and pedicel dome sensor, of the noctuid and saturniid antennae responds to visible radiation.

At Tifton data for the oxygen consumption of the larval and pupal stages of the corn earworm were obtained. On the basis of microliters per milligram per hour the pupae exhibit a typical U-shaped curve, while larval curve is inversely related to total weight. Also, the corpora alata, corpora cardiaca, and the prothoracic glands have been located and described.

#### B. Insecticidal and Cultural Control

1. Western Bean Cutworm. At Twin Falls, Idaho, trichlorfon in baits or as sprays or dusts, and azinphosmethyl and Bay 39007 as sprays were less effective than DDT for western bean cutworm control. However, 5% trichlorfon dust gave good control.

2. Beet Leafhopper. At Twin Falls the crested wheatgrass reseeding program and a dry season reduced Russian-thistle stands and resulted in one of the lowest fall leafhopper populations ever recorded. As a result, little damage was caused by the beet leafhopper in the Magic Valley of Idaho during the spring of 1967.

3. Cabbage Looper. At Charleston, S.C., 54 chemicals were laboratory bioassayed for toxicity to cabbage looper larvae. Three showed a high order of toxicity. Six other candidate materials showed sufficient promise to justify further trials. Weekly applications of nine were superior for looper control on field-grown fall cabbage than the currently recommended parathion and naled. Five candidate materials gave better looper control on spring cabbage than the currently recommended mevinphos.

4. Southern Potato Wireworm. Seventeen chemicals were compared in laboratory tests at Charleston, S.C., for toxicity to southern potato wireworm larvae. Bay 77488 and 78182 were most toxic. Dursban (2 and 4 lb/acre), S 6538 (2 lb/acre), and Bay 77488 (2 lb/acre) sprays gave 95 to 100% reductions of southern potato wireworm larvae in fall field tests.

5. Mexican Bean Beetle. At Beltsville, Md., leaf samples from bean plots at various times after treatment with granular dimethoate, UC 21149, phorate, or NIA 10242 were fed to Mexican bean beetle larvae, each at the rate of 1 and 2 lb/acre. Toxicity of all 5 materials decreased in the order given and in each case more rapidly at 1- than at 2-pound dosages. Adult bean beetles fed on harvested pods from all plots were unaffected.

6. Drosophila. In tomato field plots at Beltsville, Md., baited gallon jars dipped in 1% aqueous suspension of lindane WP and covered with lindane-treated tomato hampers and distributed at the rate of 134 jars/acre gave 85% Drosophila control. Sixty-seven and 34 jars/acre gave 64 and 46% control, respectively. The bait was vermiculite soaked with 20% granulated sugar, 6% active dry yeast, 5% glycerine, 2% apple cider vinegar, and water. Fresh jars and baskets were distributed in the plots at weekly intervals during the harvest period.

7. Corn Earworm. Low volume formulations for control of corn earworm on sweet corn found as effective as 2 lb/acre DDT EC standard were endosulfan-malathion at 0.57, endosulfan at 0.72, malathion-DDT mixture at 0.4 and 1.6 pounds, respectively, and SD-8447 at 1 lb/acre.

Results of laboratory tests using excised corn leaf segments as a substratum indicated that a water extract of corn kernels as an attractant mixed with the insecticide SD 8447, used at the rate of 0.5 ounce of active ingredient per 25 gallons of water, increased earworm larval mortality approximately 30% above that obtained with SD 8447 check. A water extract of silks increased mortality approximately 20%, while a water extract of leaves gave no apparent effect.

8. Bean Insects. At Yakima, Wash., UC 21149 was the most effective of 4 systemic insecticides for control of lygus bugs, leafhoppers, and thrips and sidedress applications were more effective than broadcast applications.

#### C. Insecticide Residue Determination

1. Greenhouse Insecticide Applications. At Beltsville, Md., 10% dichlorvos aerosol at .1 lb active ingredient per 5,000 ft<sup>3</sup> to greenhouse cucumbers, tomatoes, and Bibb lettuce gave residues in 2-hr samples of 0.01, .02, and .24 ppm, respectively. Residues in samples 1 day after treatment were less than .01 ppm.

In parallel tests with 10% sulfotep aerosols, 2-hr samples showed residues of 0.12 ppm and 0.20 ppm from tomatoes and Bibb lettuce, respectively, and residues of 0.02 ppm in both products one day after treatment.

Azinphosmethyl (50% WP) applied to cucumbers at 0.5 pound active ingredient per 100 gal water gave residues of 0.05, 0.01, and less than 0.01 ppm in 1 hr, 1 day, and 8 days after treatment. At 1.0 lb/100 gal, residues were 0.03 ppm after 1 hr and .02 ppm after 8 days. Tomatoes similarly treated with azinphosmethyl at 0.25, 0.5, and 1.0 lb/100 gal showed 1-hr residues from all treatment levels of 0.06 ppm and less than 0.01 ppm after 8 days.

2. Azinphosmethyl Drift from Airplane Application. At Beltsville, Md., azinphosmethyl at 1/2-1b/acre was applied by airplane from an altitude of 8 ft as a low-volume spray containing 22.5% of the technical compound or as an aqueous emulsion containing 2 ounces per gallon, and from an altitude of 30 ft as the low-volume spray. Maximum deposits of azinphosmethyl on glass filter paper discs attached to aluminum plates and petri dishes placed at intervals in and near the treated areas were found approximately on the line of application from the 8-ft level but at a distance of about 80 ft from this line for the application from the 30-ft level. Deposits extended to a considerably greater distance when applied from the 30-ft level than when applied from the 8-ft level. Azinphosmethyl was found in air samples at a distance of 2,000 ft from the spray area.

3. Persistence of Azodrin in Sweet Corn. At Tifton, Ga., plots of sweet corn were treated with aqueous solutions of Azodrin at rates of 0.56, 1.12, and 2.24 kg/hectare. With the highest level of treatment, initial residues in the stalks and leaves averaged 91.6 ppm, which declined to 1.09 ppm 16 days later; initial residues in the ears averaged 0.10 ppm and declined to less than 0.005 ppm within 8 days; initial deposits on the husks and silks averaged 67.0 ppm and declined to 0.13 ppm 16 days later.

4. DDT and Malathion Residues in Corn After Low-Volume Applications. Also at Tifton, plots of sweet corn were sampled after each of 5 low-volume applications of DDT (0.56 kg/hectare) and malathion (1.68 kg/hectare) at 3-day intervals and also at harvest. The highest levels found at any time were 16.5 ppm DDT and 31.8 ppm malathion after the second treatment. At

harvest (7 days after last treatment), the residues averaged 6.23 ppm DDT and 0.82 ppm malathion.

3. Corn Earworm. At Tifton, Ga., gas chromatographic methods were developed for analyzing Azodrin and Bidrin. The methods employ the Melpar flame photometric detector with the 526  $\mu$  interference filter. Samples are blended with chloroform and the raw extracts are analyzed with no further cleanup necessary. Recoveries from sweet corn spiked with Azodrin (0.05 to 5.00 ppm) prior to extraction were better than 95%.

Residues of DDT-malathion applied at 0.4 and 1.6 lb/acre, respectively, were determined on corn plants after each of 5 application dates and at harvest-time. After each of the 5 applications, residues ranged from 4 to 25 ppm. Residues averaged 6.25 ppm DDT and 0.82 ppm malathion at harvesttime on the plants.

#### D. Biological Control

1. Fall Armyworm. At West Lafayette, Ind., quantitative studies with the fall armyworm nuclear polyhedrosis virus indicate an LD<sub>45</sub> for fourth instar fall armyworm of  $2.66 \times 10^8$  polyhedral inclusion bodies. These values are much higher than the LD<sub>50</sub> values reported for fourth instar cabbage loopers treated in the same manner with cabbage looper nuclear polyhedrosis virus.

2. Cabbage Looper. At Riverside, Calif., a cytoplasmic polyhedrosis virus was found infecting cabbage looper larvae. Polyhedra were isolated and purified. The LD<sub>50</sub> for first instar larvae was approximately 1.5 polyhedra per mm<sup>2</sup> of diet surface area. Fourth instar larvae were less susceptible. Developmental rate of treated larvae is markedly decreased. Cytoplasmic polyhedrosis virus infection also appear to affect pupal and adult stages. Many pupae from larvae-fed polyhedra weighed less than half that of the control groups and increased numbers of deformed moths occurred. Pupal weight was correlated to the number of white or yellow fecal pellets excreted by the treated larvae prior to pupation. Frequently, the white fecal pellets contained large numbers of polyhedra. Cytoplasmic polyhedra in alkaline solutions of 0.1 and 0.01 M Na<sub>2</sub>CO<sub>3</sub> + 0.05 M NaCl lost infectivity potential within 10 minutes of exposure. However, .001 M Na<sub>2</sub>CO<sub>3</sub> had no effect on the infectivity of the polyhedra after 2 hours of exposure.

Commercial nuclear polyhedra preparations at the rate of  $600 \times 10^9$  nuclear polyhedra/acre of cabbages gave 61% mortality of cabbage looper larvae. Dibrom at 2 lb/acre gave better control than polyhedra sprays.

Laboratory studies on the virus-host relationship in cabbage looper pupal and adult stages at Riverside, Calif., indicated little or no effect on mating or longevity when moths were injected with 5,000-15,000 times the concentration of virus required to kill fourth instar larvae. However, treated moths were slightly infected as determined by histological examination.

Very high virus concentrations were required to prevent moth emergence by injecting polyhedra into pupae 96-120 hours old. Moths from injected pupae were often severely deformed. After injection of pupae 24-120 hours old with polyhedra virus, infected cells were found in the developing wings, compound eyes, optic lobes of the nervous system, hypodermis, trachea, fat body and developing muscle, and in the ovaries of female pupae.

An apparatus and method for comparatively rapid injection of cabbage looper larvae were designed at Riverside, Calif. A 12- to 18-in. length of polyethylene tubing was sleeved over the needle of a Hamilton Syringe. The opposite end of the tubing was then flared to accept the blunt end of a drawn-glass needle. The assembly was then placed in a microapplicator device. The polyethylene tubing allows the needle to be moved to the larvae for injection and negates individual handling of larvae. Immobilizing 10 to 20 larvae in a bead of honey on the border of a petri dish lid has also added to the speed of injection. After injection larvae are washed out of the honey with distilled water and placed in rearing containers.

Cabbage looper nuclear polyhedrosis virus free of the inclusion bodies was obtained in several ways. Polyhedra were dissolved with alkaline solutions (0.03 M  $\text{Na}_2\text{CO}_3$  + 0.05 NaCl) or virus was obtained from supernatants of diseased larvae homogenates. Assays against fourth instar larvae of four different preparations of virus liberated from polyhedra indicated that the material was infective. Virus from diseased larvae was much more infectious per unit volume and assays of two different preparations showed no statistical differences in  $\text{LD}_{50}$  values.

At Mesa, Ariz., cabbage looper field collections throughout the year from various crops and some weed hosts have shown Voria ruralis to be the most prevalent parasite of this insect. Approximately 10-15% of the looper larvae collected during the winter months and 25% from April to June were Voria parasitized. In July and August Voria parasitism reached a low level and from October to December 50% or more of the loopers gathered from the field were found to be parasitized.

Exposure of 300 looper larvae in large field cages with 100 or 200 pairs of Voria flies resulted in 50 and 80% parasitism and recovery of 145 and 484 parasite puparia, respectively.

At Charleston, S.C., field collections of cabbage looper cadavers from cabbage during the 1966 fall season disclosed 2 distinct classes of fungi occurring on several occasions, a Phycomycete, Entomophthora sphaerosperma Fresenius, and a Fungus Imperfecti, Spicaria rileyi Farlow. Immersion of cabbage plants in Bacillus thuringiensis suspensions reduced oviposition of cabbage looper adults to a greater extent than did spraying. Laboratory experiments with 10 different preparations of B. thuringiensis indicated that all 5 instars of the cabbage looper were as vulnerable to the pathogen as those of the imported cabbageworm.

At Charleston, 7 weekly applications of 2 commercial aqueous suspensions of *B. thuringiensis*, applied alone and in combination with an unpurified local strain of a cabbage looper nuclear polyhedrosis virus, proved inferior to a currently recommended parathion-endosulfan mixture and did not give adequate control of cabbage looper in field plots of 1966 fall cabbage. Parathion-endosulfan gave near-adequate protection against a caterpillar infestation that caused 61% of untreated plants to be considered ineligible to U.S. Grade 1. *Bacillus*-virus combinations were more effective than either pathogen alone and the local unpurified virus as effective as a commercial purified product. Six weekly applications of a *Bacillus*-virus combination on 1967 spring cabbage gave near-adequate control of a cabbage looper and was as effective as a parathion-endosulfan mixture. A commercial virus product used alone was about as effective as the 2 mixtures just mentioned. One commercial dust formulation of *B. thuringiensis* gave excellent control of the looper, another did not. Aqueous and wettable powder sprays of *B. thuringiensis* were less effective against the looper than the dust formulation. All *Bacillus* formulations gave good control of imported cabbageworm and diamondback moth.

3. Southern Potato Wireworm. Of 100 dying or dead field-collected southern potato wireworm larvae, 35 had protozoan infection, 13 protozoan and *Metarrhizium* infections, and 11 were infected by the fungus alone.

4. Green Peach Aphid. At Yakima, Wash., *Anthocoris melanocerus* was particularly effective in the control of the green peach aphid on broccoli and sugarbeets. The predators deposited 3 eggs per day for 50 or more days and multiplied approximately 48 times in a single generation.

In Walla Walla, Wash., studies under cooperative agreement have shown that parasitic wasps, *Aphidius pulcher* or *A. smithii*, were attracted to honeydew produced by pea aphids and to honey.

Growth chamber studies were conducted with *A. pulcher* parasitizing pea aphids on alfalfa. Mortality was very heavy at 32° C. Levels of parasitization were higher at 21° C and about 80% relative humidity than at 65% and 47% relative humidity or at 10° C. Field surveys related to mass releases of aphid parasites in alfalfa and pea growing areas showed 27% hyper-parasites on *Aphidius* spp. and 45% on *P. pequedorum* in October 1966.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Leaf Miner. At Beltsville, Md., aluminum foil, grey aluminum paint on masonite, or clear polyethylene film soil mulches failed to prevent vegetable leaf miner adults from ovipositing in snap bean plots in comparison to unmulched plots. Larvae per leaf averaged 8.1, 8.5, and 6.7, respectively, in the mulched plots and 5.0 in check plots.

2. Aphids. At Farmingdale, N.Y., aluminum foil, aluminum paint on black polyethylene film and aluminum paint on asphalt soil mulches resulted in 98% reduction of trapped aphids, whereas titanium oxide paint reduced yellow trap

collections 80%. Aluminum strips across the ends of the rows were necessary to prevent aphids from moving between strips of aluminum into the plots. Fewer plants with virus symptoms occurred in squash, cucumber, and bean plots with aluminum surface mulches than the plots with white surface mulches. Infections in check plots were significantly higher than in the white mulch. Snap bean, summer squash, and cucumber yields were higher in mulched plots than check plots.

3. Drosophila. At Beltsville, Md., (in cooperation with the Campbell Soup Company, Rancocas, N.J.) 1% apholate, 20% granulated sugar, 6% active dry yeast, and water failed to give satisfactory control of Drosophila melanogaster in 1/2-acre tomato field plots. However, a high percentage of female flies collected from the check plots were sterile and oviposition records from ripe slit tomatoes showed that the Drosophila population was lower in the experimental plots than in untreated tomatoes growing several hundred feet away.

In 24- X 24- X 6-ft plastic screen cages containing tomatoes, baits of 1% apholate (broadcast and in cartons), 0.5% ENT 51146, 2% ENT 50905, 1% apholate (cartons) plus 1 lb diazinon/acre application, or 1 lb diazinon alone reduced Drosophila populations 85% or more. Females sampled from the populations were more than 85% sterile from treatments of 1% apholate (cartons), 0.5 and 2% ENT 50905, and 0.5% ENT 51146. Sterility was less in flies from cages treated with 1% apholate (broadcast), 2% apholate, 2% ENT 51146, and 0.5% ENT 51146 plus 0.5% ENT 50882. No flies were isolated from cages treated with diazinon and diazinon plus apholate due to the low number of flies.

4. Cabbage Looper. At Mesa, Ariz., 413 traps, each with two 15-watt blacklight fluorescent lamps were placed in operation on March 6, 1967, on a 2,500-acre partially isolated ranch near Red Rock, Ariz. The traps will be operated continuously throughout the year to determine the possibility of preventing population increases and consequent injury from several species of lepidopterous insects affecting lettuce, particularly the cabbage looper. All traps are baited with a synthetic female cabbage looper sex attractant. A check area without intensive light trapping is maintained approximately 10 miles away from the Red Rock area. This is a cooperative project with the Agricultural Engineering Research Division.

A maze type mechanical trap baited with the female cabbage looper sex attractant caught more male cabbage looper moths than a pheromone baited 15-watt blacklight trap. In addition, large numbers of male granulate cutworm moths were caught.

A new type of dispenser for cabbage looper female sex attractant has been developed at Mesa and consists of a cotton thread wick in an 8 mm glass tube. The pheromone is placed undiluted in the tube and one filling should last the entire season.

At Riverside, Calif., synthetic cabbage looper sex pheromone on sand in 50 ml beakers in combination with blacklight traps, caught 13 times more cabbage

looper males than light traps alone and 2 times more males than traps baited with 100 live females. The pheromone on sand remained attractive for more than 48 days.

Sex pheromone baited electrocutor grid traps mounted above tub canisters containing emulsified water were found more effective for trapping cabbage looper males than pheromone-baited survey light traps. When the former was supplemented with blacklight, 13 times more male moths were trapped per night. Pheromone-baited electrocutor grid traps without blacklight were quite specific for the cabbage looper males and less than 10% of the total catch were of other species. A canister to trap stunned moths was found essential as 81 to 83% of the trapped moths were found in the canister.

Cabbage looper moth catches from barrel and survey type blacklight traps baited with 100,000  $\mu$ g of pheromone-treated sand placed at the bottom of the light fixtures caught 1.6 times more male moths in an 8-day period than similar traps baited with pheromone on top of the lamp housing and 2 or 3 times more than survey light traps baited with pheromone at base of the lamp housing.

At Riverside, Calif., a Y-tube apparatus was designed and used to bioassay commercial preparations of the synthetic cabbage looper sex pheromone. The AC50 (attractive concentration--50% response) of the pheromone in ether solution and applied on filter paper was found to be 1.08  $\mu$ g and 95% confidence interval of 0.89 to 1.31  $\mu$ g. By determining the dissipation rate of 5  $\mu$ g on filter paper, the actual amount of pheromone to which 50% of the moths responded to was calculated to be about 91 ng/m<sup>3</sup> of air.

To date, 20 analogs and homologs of the sex attractant supplied by the Pesticide Chemicals Research Branch have been bioassayed and all found at least 500 times less active than the pheromone.

At a constant dosage of the cis isomer (1  $\mu$ g) and varying dosages of the trans isomer (0 to 500  $\mu$ g) of the cabbage looper sex pheromone, male response was reduced at 10  $\mu$ g or more of the trans isomer. This effect was produced, but to a lesser extent, by 7-dodecyn-1-ol acetate and dodecen-1-ol acetate.

5. Cucumber Beetles. At Charleston, S.C., in cooperation with chemists at Beltsville, Md., approximately 134 chemical fractions of the natural female lure were bioassayed as male attractants. Six of the fractions have been attractive to male beetles.

6. Corn Insects. A laboratory procedure has been worked out at Tifton, Ga., for the collection and isolation of sex pheromone of corn earworm. This pheromone caused a marked response in copulatory activity of corn earworm males when a small amount of the material was aspirated into cages, but no increase was noted in the frequency of mating or the number of spermatophores passed.

Studies with the light trap-chemosterilant feeder were conducted with the corn earworm in Georgia and the effects of 0.15, 0.3 and 0.6% tepa solutions

on field-collected earworm moths were recorded. The 0.15% solution reduced but did not eliminate egg hatch in all instances when the material was held for as long as 7 days in the field and bioassayed after each 24-hour period. The 0.3 and 0.6% concentrations reduced egg hatch and oviposition. Some increases were noted in mortality for each of the treatments indicating that the material is toxic to corn earworm moths in higher concentrations.

In cooperation with agricultural engineers at Tifton, ultrasonics was evaluated for its effectiveness as a repellent to the corn earworm moths. The sound was beamed over the field with a 2-in diameter LTV transducer which emitted sound waves at a frequency of 21 kcs up to a sound intensity of 84.5 decibels, as measured on a B&K sound meter on the B scale. The transducer was revolved at 324 rpm from 6 pm until 6 am during the tests. Effectiveness of the sound was determined by counting corn earworm eggs on plants and collecting moths near the transducer in light traps. There were no significant differences between the number of adults or number of eggs near the transducer and in the check area.

#### F. Evaluation of Equipment for Insect Detection and Control

1. Corn Earworm. In cooperation with agricultural engineers at Tifton, a Dynafog aerosol generator was tested for control of the earworm. DDT was fogged directly onto the corn each day during the silking period. When the corn ears reached optimum roasting ear stage, they were evaluated for insect damage. About 90% of the ears treated were marketable, which was about equal to DDT applied by conventional spray equipment.

2. Southern Potato Wireworm. At Charleston, S.C., 4 blacklight traps with one 15-watt lamp each caught from 3,257 to 5,323 adults of *C. falli*, with an average of 4,357, between mid-August and late October in sorghum fields. Soil samples indicated that the traps did not significantly reduce the over-wintering larval population of the insect 10, 50, and 100 feet from the traps. No differences were found between numbers of wireworm larvae in the soil at the various distances from the traps. Traps located 200 feet inside cultivated fields did not catch significantly higher numbers of adults than did traps placed in narrow uncultivated areas between these fields and wooded areas. Limited observations indicated that the adults do not disperse rapidly through woodlands to nearby uninfested recently-cleared areas. Of 1,779 marked adults released in a well-isolated field, 5.1% were recovered by the end of a week. Fifty-one percent of those recovered were found in areas 10 feet from the release point. Nine marked beetles were recovered 900 feet from point of release; none were found at a 1,160-foot distance.

3. Cabbage Looper. At Forest Grove, Oreg., in cooperation with the Birdseye Division of General Foods, applications of DDT-parathion, mevinphos, or parathion at recommended rates applied to broccoli by helicopter in 15 or 20 gallons of water per acre at approximate 10-day intervals from August 12 to October 7, 1966, kept looper populations at low levels throughout the season.

4. Black Bean Aphid. At Forest Grove, Oreg., 1.75 lb/acre of malathion was applied to pole beans by helicopter at 60 mph parallel to the rows and 8- to 10-ft above the foliage or by airplane at 90 mph across the rows at the same height. Six days after application, from 3 aphid colonies in each field, there were 4 adults and 16 nymphs found remaining on one vine from the helicopter application, while 7 living aphids were found in airplane application plots.

5. Spray vs. Dust Parathion Residue Applications. At Forest Grove, Oreg., parathion, 0.5 lb actual per acre, was applied as 25 lb of 2% dust or as a spray in 40 gallons of water per acre of broccoli in each case. The dust was applied from overhead nozzles, both with and without a static electrical charge, while the spray was applied from the conventional trailing boom position. More than 2 times as much parathion was recovered by chemical analysis from the tops and bottoms of the dust-treated foliage, as compared to the spray-treated foliage.

6. Aircraft Applied Ultra Low Volume Malathion Spray for Lygus. At Forest Grove, Oreg., technical malathion applied August 15, 1966, at 8 oz per acre by fixed-wing aircraft to lima beans gave excellent commercial control of lygus bug adults and nymphs within 18 hours after treatment and more complete reduction in lygus populations 9 days after application.

7. Bals-Turbair Spinning Nozzle Mounted on a Bell Helicopter. A single Bals-Turbair electric spinning nozzle mounted on the aft spray boom mounting of the helicopter, facing back, angled down at 45°, has consistently produced an overall swath width exceeding 100 feet and is well adapted for ULV applications.

#### G. Varietal Evaluation for Insect Control

1. Leaf Miner. At Beltsville, Md., larval mortality of the vegetable leaf miner in 16 tomato varieties averaged 16% in 25-day-old plants, 37% in 50-day-old plants, and 43.7% in 90-day-old plants. Varieties also differed in levels of resistance to this pest.

Larval mortality of the vegetable leaf miner was also found to increase in 17 tomato varieties and 19 chrysanthemum cultivars with decreased temperatures. In tomato, larval mortality for 17 varieties averaged 6% at 78.8° F, 8% at 74.5° F, and 15% at 70.0° F. In chrysanthemum, larval mortality in 19 varieties at the same three temperatures averaged 42%, 51.4%, and 65%, respectively. Leaf miner larval mortality in lima beans did not appear affected by temperatures from 59.5 to 95.8° F.

In cooperation with the Crops Research Division, all lines of Lycopersicon hirsutum tested were highly resistant to vegetable leaf miner oviposition, indicating resistance for leaf miners for this entire plant species. All lines of L. peruvianum and esculentum tested proved susceptible.

2. Two-Spotted Spider Mites. Resistance to two-spotted spider mites in 7 accessions of Lycopersicon hirsutum and L. hirsutum glabratum under greenhouse conditions was observed at Beltsville, Md. Adult and nymphal mortality was higher on the more resistant accessions.

3. Greenhouse Whiteflies. At Beltsville, Md., whitefly egg and first nymph counts on most Lycopersicon hirsutum (tomato) lines tested have been generally as high as on L. esculentum but higher nymphal mortality and delayed nymphal development have been observed on some lines of the former species. Within two accessions of L. hirsutum, plants are virtually free of nymphs. Adult whiteflies confined to the leaves of the plants died within five to fifteen minutes. Contact with the leaves also proved fatal to mealworm adults.

4. Potato Aphid. At Beltsville, Md., all tomato seedlings with L. esculentum parentage and those of the available accessions of L. pimpinellifolium, hirsutum, and hirsutum glabratum were heavily colonized and mostly killed by potato aphids. Six accessions of L. peruvianum showed a high level of resistance. Attempts to artificially infest resistant peruvianum plants from seedling stage to the seventh true leaf stage were unsuccessful due to high aphid mortality. The few adult females which settled on the resistant plants failed to produce nymphs. Segregation for resistance was observed in all resistant lines and this is to be ascribed to the characteristic self-infertility of individual L. peruvianum plants.

5. Tobacco Flea Beetle. At Beltsville, several accessions of L. hirsutum and L. hirsutum glabratum showed a high level of resistance to adult tobacco flea beetles under field and greenhouse conditions. When given a choice of Lycopersicon species seedlings under caged and natural field conditions, beetles did not feed upon the hirsutum accessions but severely damaged the accessions of L. peruvianum, L. pimpinellifolium and L. esculentum.

When confined upon each tomato line separately, beetles fed only sparingly on senescent yellow leaves of hirsutum accessions and extensively and indiscriminately on leaves of all other Lycopersicon species.

6. Lygus. At Riverside, Calif., 35 lima bean entries in the seedling stage were screened in preference tests for resistance to lygus. Two breeders' lines were least preferred as 76% less lygus bug nymphs were found on them as compared to concentrated Fordhook. In contrast, on two other lines 88 to 94% higher infestation occurred.

7. Sweetpotato Insects. At Charleston, S.C., resistance factors involved in sweetpotato resistance to insects have been shown to be a thick cortex imparting a degree of tolerance, the periderm of most but not all varieties provides protection against insect damage and the flesh of a few varieties is non-preferred by some insect species either because it lacks a feeding stimulant or contains a feeding deterrent.

8. Turnip Insects. At Charleston, S.C., aphids reproduced 3 times as fast on a susceptible turnip variety (Pomeranian) as on a resistant variety (Shogoin). Shogoin also appeared resistant to green peach aphids.

9. Banded Cucumber Beetle. At Charleston, S.C., 430 watermelon, 1,371 cantaloup, and 688 cucurbit varieties and plant introductions were screened for seedling resistance to banded cucumber beetles. One resistant watermelon variety (Sugar Loaf) was found. Approximately 1.5% of the cantaloup introductions and 22% of the varieties were classed as resistant. The cucurbits were relatively tolerant to banded cucumber beetle, Diabrotica balteata LeConte, feeding and approximately half of the varieties and 1.8% of the introductions were classed resistant. In tests with selected susceptible and resistant lines, the spotted cucumber beetle, Diabrotica undecimpunctata howardi Barber, showed an almost identical preference as the banded cucumber beetle. The only factor identified was the absence of cucurbitacin, a group of bitter substances that have been demonstrated to be Diabrotica feeding stimulants. These substances are believed to be the major factor responsible for susceptibility in cantaloups and watermelons. In summer squash there is some evidence that a repellent or feeding deterrent may be involved.

10. Leafhoppers. In India (A7-ENT-44) techniques have been developed for evaluation of resistance to host food by measuring feeding on excised leaf tissues. Differences in leafhopper growth and ovarian development were observed.

11. Corn Earworm. At Tifton, Ga., corn inbreds 81-1 and 471-U6 make up the desirable and earworm resistant sweet corn "Walter's White" and are difficult to maintain and use in a crossing program. Several hybrids made from inbreds produced in a backcrossing program with 81-1 and 471-U6 have shown considerable promise in retaining quality and earworm resistance. Improvement has been made in vigor and shortening the silking date of the 81-1 backcrosses, at least as inbreds. Improvements have also been made in 471-U6 backcrosses as to ease of handling in a hand-pollination program.

A study of the relationship of corn earworm damage with ear husk tightness and larval development indicated highly significant differences among corn lines for husk tightness, depth of larval penetration, and larval weights (7 days after infesting). A highly significant negative correlation coefficient ( $r = -.513^{**}$ ) indicated a relationship between husk tightness and depth of larval penetration. Husk tightness and larval weights from field ears had a highly significant negative correlation ( $r = -.582$ ). Depth of larval penetration in field ears at 7 days and larval weights from these ears showed a highly significant correlation ( $r = -.541^{**}$ ).

At State College, Miss., corn lines selected for varying chemical content were evaluated for corn earworm and fall armyworm resistance. In a field test, corn kernels with low amylose content seemed to have more earworm damage than kernels with high amylose content. In addition, kernels with high lipid or high carotene content had more damage than kernels with low lipid or low carotene. In general, these results are in agreement with a similar test

conducted in 1965. A second part of this test involved a fat analysis of larvae reared on these same corn lines. Indications are that larvae reared on the low amylose corn lines contain the least fat, while larvae reared on the high protein lines contain the most fat. Larvae from the high lipid line contained more fat than larvae from the low lipid line. The opposite was true for the high and low carotene lines.

12. Cabbage Maggot. At Yakima, Wash., some varieties of red radishes were found significantly more resistant than some white radishes to attack by the cabbage maggot.

Also, a moderately early greens type turnip was found more resistant than 38 other varieties to attack by the cabbage maggot. However, this turnip was very susceptible to both the green peach aphid and the cabbage aphid.

#### H. Insect Vectors of Diseases

1. At Beltsville, Md., the green peach aphid transmitted the virus associated with russet crack of sweetpotato to indicator plants Ipomea var. Scarlet O'Hara and I. setosa and reinfected sweetpotatoes.

The virus appears to be picked up by 10-minute feeding on source plant and transmitted in the non-persistent manner.

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## POTATO INSECTS

Entomology Research Division, ARS

Problem. Control of insect pests is essential to the profitable production of high-quality potatoes. There is a continuing need for research to improve present control methods as insects develop resistance to insecticides and the public demands safer, more effective, and more economical methods of insect control. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is an especial need for research on the biological control of potato insects; and for research on the evaluation of potato varieties for insect resistance. Concern over problems associated with insecticides which may also include residues in the soil, contamination of non-target areas, and interference with the work of natural enemies of insect and mite pests, requires that an increasingly strong research effort be concerned with development of non-chemical methods of insect control or of ways of using chemicals that will avoid objectionable side-chain effects.

## USDA AND COOPERATIVE PROGRAMS

Basic studies on the biology, ecology, and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control are conducted by the Department at Yakima, Wash., Orono and Presque Isle, Maine, Beltsville, Md., and Charleston, S.C., in cooperation with the respective State experiment stations, the Washington Department of Agriculture, the Washington State Potato Commission, and industry. Studies on plant resistance are conducted under grants at Pennsylvania State University and, in cooperation with the Crops Research Division, at the Iowa State University of Science and Technology. (Biological control studies at the University of Maine conducted under a cooperative agreement have been completed.)

The Federal scientific effort devoted to research in this area totals 3.6 professional man-years. Of this number 0.1 is devoted to basic biology; 1.1 to insecticidal and cultural control; 0.4 to insecticide residue determination; 1.1 to biological control; 0.1 to insect sterility and attractants; 0.1 to evaluation of equipment for control and detection; 0.1 to varietal resistance; 0.3 to insects that spread potato diseases; and 0.3 to program leadership.

In addition Federal support of research in this area under grants and cooperative agreements totals 0.8 man-years devoted to plant resistance to insects.

Research under the PL 480 grant program is being supported in India and Poland. Projects in India include research on hereditary variation in the ability of Myzus persicae to transmit potato leaf roll and virus Y (A7-ENT-33) and on physiological factors governing susceptibility or resistance of crop plants to leafhoppers (A7-ENT-44). In Poland research is underway on the influence of fatty acids and alpha-tocopherol on the lipid metabolism and physiology of the Colorado potato beetle and on vitamin activity in coming generations (E21-ENT-18).

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 4.6 professional man-years is devoted to this area of research.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Physiology, and Nutrition

1. Pacific Coast Wireworm. The presence of a sex pheromone in adult Pacific Coast wireworm females that is highly attractive to male wireworms was demonstrated at Yakima, Wash.

2. Aphids. In Maine, peak aphid populations on untreated potatoes were only about 1/4 as high in 1966 as aphid populations at a comparable time in 1965 and below the threshold numbers where feeding damage reduces potato tuber yield. Entomogenous fungi-infested potato aphids were found on potatoes July 18. The resulting epizootic was virtually complete August 25 and a second epizootic during the last half of August reduced green peach aphid populations. The most common and effective species of fungi were Entomophthora thaxteriana and E. aphidis. A third, less common species was E. planchoniana. Parasite populations were below average as were number of eggs of certain predaceous insects; however, predaceous larvae and adults generally were more abundant in 1966 than in 1965.

In northeastern Maine high buckthorn aphid populations in 1967 were much earlier and larger than during the preceding 4 years on buckthorn, the primary host and potatoes. Entomogenous fungi and parasites were less effective against the buckthorn aphid during late summer and fall 1966 than during any comparable period since 1962. Late spring Canada plum surveys indicated that green peach aphid early summer populations on potatoes in northeastern Maine would be low.

##### B. Insecticidal and Cultural Control

1. Aphids. Good to excellent potato aphid control was obtained on field grown Katahdin potato plants from single spray applications of Union Carbide UC-20047A (0.75 lb. or 0.38 lb./acre), duPont 1179 (9.50 lb. or 0.13 lb./acre), or Chipman RP-11974 (9.24 lb./acre) in studies in Maine. None of these treatments was superior to parathion (0.1 lb./acre), which controlled potato and green peach aphids. UC-20047 and duPont 1179 (0.5 lb./acre) also controlled green peach aphids.

Ground equipment sprays containing NIA-10242 and Azodrin were about as effective as endosulfan for green peach aphid control on potatoes in Washington.

At Yakima, Wash., emulsifiable concentrates (EC) and ultra low volume (ULV) formulations of malathion applied at 1 lb./acre with an experimental ground sprayer were not effective against the green peach aphid. Low volume applications of endosulfan EC or oxydemetonmethyl EC were more effective than an experimental ULV-endosulfan formulation. The addition of Triton-X to some of the ULV sprays did not improve aphid control.

2. Wireworms. At Yakima, Wash., broadcast applications of diazinon, parathion, and Stauffer N-2790 gave best wireworm control.

Soil applications of a mixture of EPN and parathion (1/2 each) were superior to the same total amount of toxicant applied as EPN or parathion alone for Pacific Coast wireworm control. Also promising was a grits formulation of Stauffer N-2790.

3. Two-Spotted Spider Mite. Azodrin gave outstanding control of the two-spotted spider mites on potatoes in Washington.

#### C. Insecticide Residue Determinations

1. Wireworms. At Yakima, Wash., a single DDT spray (10 lb) in August prevented wireworm damage to potatoes and harvested tubers contained less than 0.01 ppm DDT.

2. Aphids. In Maine, greenhouse bioassays starting March 25, 1967, showed no residues lethal to green peach or foxglove aphids feeding on caged Katahdin potato foliage of plants from tubers harvested the preceding fall from plants side dressed July 18, 1966, with 1 lb/acre of Union Carbide UC-21149, disulfoton, or Niagara NIA-10242-10 granules.

A ground spraying apparatus was developed by the Agricultural Engineering Research Division in Washington for the application of ultra low volume sprays. Application of malathion with the apparatus showed that distribution was satisfactory, but of the theoretical 1.46 kg/hectare applied only 0.24 kg/hectare was deposited on the filter paper samples placed on the ground. The amount of insecticide which reached the ground did not compare favorably with that deposited by aircraft.

At Yakima, Wash., 10% disulfoton granules were applied as follows: (1) in band treatments at 2.24, 3.36, and 4.48 kg actual per hectare; (2) as side dressings at various periods after planting with 3.36 kg per hectare; and (3) as a combination of the 3.36-kg banding with the 3.36 kg side dressing. Harvested potatoes contained from less than 0.05 to 0.29 ppm for all three treatments.

Also in Washington, endosulfan, malathion, and oxydemetonmethyl were applied to potato leaves as emulsifiable concentrates with conventional ground spraying equipment and as ultra low volume (ULV) sprays with an experimental ground spraying apparatus developed by the Agricultural Engineering Research Division. The insecticide, type of treatment, application rate in kilograms per hectare, and the average residue in ppm immediately after application and 14 or 15 days later were as follows: endosulfan, ULV, 0.9, 23.0, 12.; endosulfan, EC, 1.1, 89.9, 3.9; malathion, ULV, 1.7, 8.5, 0.04; malathion, EC, 1.1, 39.8, 0.01; oxydemetonmethyl, ULV, 0.6, 18.8, 0.1; oxydemetonmethyl, EC, 1.1, 214.6, 2.1.

#### D. Biological Control

1. Seven-Spotted Ladybird Beetle. In Maine, the introduced 7-spotted ladybird beetle was found to apply an adhesive substance anteriorally on each egg at oviposition. Studies at Rutgers University suggested that egg masses might be successfully broken up by placing a water soluble substance between the adhesive and the oviposition substrate. A coating of 15-33% gelatin proved suitable for this purpose. A satisfactory device for obtaining eggs of this predator was developed. One worker can now obtain eggs from approximately 800 females per day, compared to previous methods when eggs from only 80 females could be obtained.

Seven-spotted ladybird beetle and Chrysopa spp. eggs have been distributed in water or sucrose solution sprays without excessively suppressing hatchability. Chrysopa egg hatch was markedly reduced when applied at a pressure of 30 lb/in<sup>2</sup>; C. septempunctata egg hatch was reduced when lower spray pressures were used.

Studies in Maine indicated that diapause can be broken and oviposition maintained by exposing adult C. septempunctata to a nearly continuous source of light from a frosted 100-watt incandescent bulb. Adult diapause appeared to be influenced by food in the larval stage. Surplus food in the adult stage is necessary for initiation and/or maintainance of oviposition. For adult pairs this is in excess of approximately 200 green peach aphids per day. At lesser numbers of aphids, oviposition could be increased by supplying a liquid food supplement every other day.

Factors affecting oviposition of the predator, Coccinella septempunctata, were found to be crowding in the oviposition cage and the chemical nature of materials covering the cage or used to band-treat cage walls. Crowding was successfully overcome by providing extra resting space through introduced excelsior. A narrow band of "Teflon" on the cage walls, or a cage covering of Saran wrap caused the females to become very active and deposit many small clusters of eggs.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

Tests were initiated in Maine to determine the possibility of eliminating the green peach aphid in a semi-isolated 100-square-mile area by removing its

overwintering host plant, Canada plum. In 1967 surveys indicated that 70% of the thickets were located in 1966 and the remainder were removed in 1967.

In 1967 a second experiment was initiated to remove Canada plum in a non-isolated 315-square-mile area in central Aroostook County. Approximately 450 Canadian plum thickets were found. These are being removed.

#### F. Varietal Evaluation for Insect Control

1. Aphids. Under competitive conditions in Maine larger populations of potato and green peach aphids developed on Katahdin than on Kennebec potato varieties, but the latter variety had more buckthorn aphids. In one location Kennebec potatoes had more leaf-roll infection than Katahdins but in three locations the reverse was true.

2. Two-Spotted Spider Mite. At Pennsylvania State University investigations have been initiated to study population increases of two-spotted spider mites and factors involved in spider mite host association under a grant.

3. Potato Leafhopper. Histochemical studies in Iowa indicate positive mucopolysaccharide reactions of fluids discharged into plant tissues along with potato leafhopper eggs. Salivary secretions of the leafhoppers are being tested for suspected hydrolytic enzymes. Studies of postembryonic development show discharge of yolk laden primary oocytes from the ovarioles on the fourth day of the adult stadium and presence of spermatozoa in seminal vesicles on the first day. Apparently feeding must immediately precede oviposition; refusal to feed prevents oviposition.

#### G. Insect Vectors of Disease

1. Aphids. Leaf-roll spread in susceptible Chippewa variety potatoes ranged from 0.3 to 1.3% in Maine where insecticides were applied. In untreated, less susceptible Katahdins leaf-roll spread averaged over 6%. There was no differences in leaf-roll spread between plots treated with several effective systemic aphicides applied in the planting furrow, or of two foliar spray applications of a mixture of methyl parathion and endrin.

In Maine 3 or 6 weekly applications of a special mineral oil emulsion in water provided a highly significant degree of protection (about 60%) to Green Mountain potatoes from potato virus-Y infection spread by green peach aphids. Six applications gave better protection than three. There were no differences in sizes or trends of aphid populations on Chippewa potatoes sprayed 4 times at weekly intervals and 2 times at biweekly intervals with 2 1/4 lb per acre of chlorocholine or with water alone.

The unusually mild winter of 1966-67 in Washington was extremely favorable for the survival of green peach aphid summer forms on winter hardy weeds.

In eastern Washington green peach aphid overwintering eggs are most commonly laid on peach but occasionally on apricot. Observations in the spring of

1966 indicated that small numbers of the green peach aphid are deposited on Solanum dulcamara, a woody, solanaceous plant. Apterous forms were found on this shrub May 23, 1966, at Walla Walla and May 21, 1967, at Caldwell, Idaho.

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## DECIDUOUS FRUIT, TREE NUT, GRAPE, AND BERRY INSECTS

Entomology Research Division, ARS

Problem. Insects and mites are important limiting factors in production of high quality fruits, nuts, grapes, and berries, shortening the profitable life of the trees, vines, or plants, and reducing the yield or quality of the crop. Certain insects and mites transmit diseases that adversely affect the life and productivity of the host plant. No one method of control is fully satisfactory and methods that are effective now may not be so later. At present biological, cultural, and other nonchemical methods of control are available for comparatively few insect pests. Much dependence is placed on insecticides for control. The continued use of insecticides, however, is complicated by the occurrence of insecticide-resistant strains of an increasing number of insects and mites, by the need to avoid objectionable residues on fruits and berries and on their waste products used for livestock feed, by their detrimental effects on beneficial insects, fish, and wildlife, and by contamination of non-target areas. There is a continuing need for research to develop more selective, economical, and safer insecticides; and for intensified research on alternate types of control such as those based on the use of attractants, repellents, traps, insect-resistant varieties and materials that affect insect growth and reproduction, including chemosterilants. More research is needed on integrated chemical-biological control programs with less intensive insecticide usage, so that the maximum benefits from parasites, predators, and pathogens may be realized. Research is required to determine more fully the role of insects in the transmission of important diseases affecting the production of these crops, and to determine host preferences, distribution, and habits of the insect vectors, and method of population suppression. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases.

## USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic studies and practical solution of growers' problems. Research on pome and stone fruit insects is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on insects affecting the production of grape, blueberry, and black walnut at Wooster, Ohio, in cooperation with the Ohio Experiment Station; and on strawberry insects at Beltsville, Md., and Riverside, Calif. Research on insects and mites in relation to the transmission of diseases of deciduous tree fruits is carried on at Riverside, Calif., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the respective State experiment stations and the Crops Research Division. Work is also being conducted

under grants at the Washington, North Carolina, California, Oregon, Kentucky, Pennsylvania, Maine, Texas, New York, Ohio, and Colorado Agricultural Experiment Stations, and at Brigham Young University in Utah.

The Federal scientific effort devoted to research in this area totals 20.0 scientific man-years. Of this number 3.9 is devoted to basic biology and nutrition; 5.1 to insecticidal control; 1.1 to insecticide residue determinations; 2.9 to biological control; 4.8 to insect sterility, attractants, and other new approaches to control; 0.2 to evaluation of equipment for insect detection and control; 0.8 to insect vectors of plant virus diseases; and 1.2 to program leadership.

In addition Federal support under grants provides for a total of 5.4 scientific man-years of research in this area. Of this total 1.8 is devoted to basic biology, physiology, and nutrition, 1.0 to biological control, 2.3 to insect sterility and attractants, and 0.3 to varietal resistance.

Research under PL 480 grants is underway as follows: Israel (A10-ENT-13) on factors influencing variations in insecticide resistance, including resistance of spider mites to insecticides; Poland (E21-ENT-8) on study of mites in orchards with special reference to the relation between phytophagous and predaceous species, and (E21-ENT-16) on populations trends of predaceous arthropods in apple orchards sprayed with pesticides and the influence of the trends on population density of phytophagous mites and other pests; and Yugoslavia (E30-ENT-2) on leaf miners in orchards and (E30-ENT-4) on spider mites in orchards.

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 48.5 professional man-years is devoted to this area of research.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Physiology, and Nutrition

1. Codling Moth. Expansion of facilities at Yakima, Wash., facilitated rearing up to 8,000 moths per day on an artificial medium. Moths reared for 34 consecutive generations on this medium showed no retrogression compared to stock reared on natural foods. Cost per 1,000 adults was reduced from \$5.53 (materials only) in 1965 to \$1.90 in 1966. Work in progress shows promise of reducing the latter by one-third. Costwise, the artificial medium holds a favorable position over apples but efficient egg utilization and control of fungal contaminants continue to be intermediate problems. Progress was made in developing equipment designed to mechanize the rearing procedure.

Studies at Washington State University under a grant indicate that photoperiod is more significant than low temperature for inducing diapause in the Washington strain of the codling moth. When held on 16-hour photoperiod, significant pupation occurred even at 15°C, a temperature near the developmental threshold. The studies indicated that photoperiodic induction of

diapause was most effective within the first 3 larval stadia. Also photo-period appeared to be the most significant environmental factor for breaking diapause. Diapause larvae held for three weeks at  $-9^{\circ}\text{ C}$  did not continue development when placed at  $26^{\circ}\text{ C}$  on 12-hour photoperiod, but did pupate at the high temperature when on 16-hour photoperiod.

In studies involving diapause prevention and termination with skeletal photo-periods, discontinuous light supplementation at the proper time significantly reduced diapause normally experienced at short photoperiod, and the nature of supplemental light governed the time for greatest effect. When the last daily light experienced was measured from start of the continuous 10-hour exposure, the following peaks of pupation were obtained: Single flash at 15 hours yielded 90% pupation, 4 flashes at 17 hours yielded 80% pupation, 1 flash at 16 hours yielded 82% pupation. Light supplementation with flashes was not successful in breaking diapause.

2. Peach Tree Borers. The sex ratio of 73,667 adult lesser peach tree borers reared in the Vincennes, Ind., laboratory, and 18,638 additional adults recovered from caged peach wood was determined at 53 males:47 females.

In dissections at Vincennes of 47 living female lesser peach tree borers caged with 240 males, each female contained a single spermatophore, indicating that the females had mated only once.

In temperature-humidity tests with the lesser peach tree borer at Vincennes, egg hatch was nearly 81% at  $70^{\circ}\text{ F}$ , while only 54% hatched at  $90^{\circ}\text{ F}$ . The incubation period was 9 days at  $70^{\circ}\text{ F}$ , compared to 6 days at  $90^{\circ}\text{ F}$ . There was a general trend of increased embryo survival as the humidity increased, reaching maximum survival in the 72-78% relative humidity range.

At Fort Valley, Ga., peach tree borer cocoon collections and adult emergence records showed that cocooning was maximum at the end of August and adult emergence was maximum in mid-September. First moth emergence was recorded in mid-June; subsequent emergence was low until late August.

Field-collected peach tree borer cocoons held in environmental chambers at Fort Valley under altered days emerged as adults and the females began calling in synchrony with the altered day. Emergence came about  $\frac{1}{2}$  hour after "sunrise" and calling started  $3\frac{1}{2}$  hours after female emergence. Males emerged about 8-10 minutes before females. Entrainment was virtually complete, though the period of entrainment was not determined. The emergence and calling rhythms were moved both forward (6:00 AM EST "Sunrise") and back (10:00 AM EST "Sunrise") from the solar day.

At North Carolina State University in research under a grant, peach tree borer larvae were reared on green apples or peach seedlings, transferred to artificial medium or kept on green apples. Mating activity was initiated in laboratory cages soon after lights were turned on. Females usually mated within a few hours after emergence and apparently only mated once. Males were mated daily to virgin females for 6 days without any effect on fertility.

3. Plum Curculio. At Fort Valley, Ga., biological studies on non-diapause plum curculios enabled further improvement in laboratory rearing procedures. Eggs laid per apple was closely related to the size of apple and surface area exposed; the smaller apples were superior. Also more and larger larvae were produced per gram of apple from 12-gram apples than from 20-gram apples. Larvae placed in soil for pupation reached their pupation depth in 3 days and started forming pupation cells on the fourth. Pupae began forming on the ninth day and adults appeared on the 17th or 18th day. Some adults had worked their way to within an inch of the soil surface by the 24th or 25th day. The larvae pupated well below the 1/2 - 2 inch depth usually reported. High soil moisture was very detrimental to pupating larvae. When surface evaporation from pupation trays was restricted, adult emergence fell from 90% to 57%.

Larvae weighing less than 17 mg failed to survive the pupal stage as well as larger larvae. Ten percent fewer small larvae emerged as adults than larvae weighing over 17 mg. Larvae that pupated at 80° F did not survive the pupal stage as well as those that pupated at 75° and 70° F. Ten percent fewer adults emerged from 80° conditions than from the 70° F. chambers. The minimum pupation period was shortened from 35 days at 70° to 27 days at 80° F. The small adults arising from small larvae reared under crowded conditions were as long lived as larger adults. For 8 adult weights ranging from 8.9 to 10.5 mg, there was about 50% mortality after 10 weeks of adulthood.

4. Pecan Insects. In mating studies of the hickory shuckworm at Albany, Ga., emanations from developing pecan foliage, phylloxera galls, and pecan nuts stimulated moths to mate. The stimulation was not a tactile response nor was it induced by emissions from mature pecan foliage or pecan nut extracts made following present procedures. Water, hexane, acetone, and chloroform extracts also failed to elicit a mating response.

A method was developed at Albany for rearing the hickory shuckworm on an artificial diet. The refinement of procedures, surface sterilization of the eggs and the addition of antibiotics to the diet showed promise of reducing contamination and increasing yields.

Other studies on hickory shuckworm at Albany showed that the larvae pass through five distinct stadia and overwinter in the fifth. Storage of fifth-instar larvae in shucks, nuts, or artificial diets followed by rearing of the moths as needed provided the laboratory with more than 28,000 moths; larval mortality during storage was not excessive. The production of large quantities of moths during July and August by this method for sterility or attractant studies appeared feasible. Moths were also stored in polyethylene containers for as long as 15 days at 10° C.

Dissection of 135 female hickory shuckworm moths collected in blacklight traps at Albany yielded an average of 1.56 spermatophores in the bursa copulatrix of each female. Sixty-nine percent had mated once, 17% twice, and the remainder 3-6 times. There appeared to be a correlation between spermatophore size and number; small spermatophores usually were found in larger numbers. Perfectly-formed spermatophores were often found inside the shell of larger

ones. Sometimes a third one was found inside the second. Often, small spermatophores were packed sardine-like in the bursa copulatrix, partially inside each other or in no particular order.

At Albany, two species of spittlebugs that attack pecans oviposited readily in cages containing living pecan leaves. The eggs, which were deposited under the epidermis of new terminal growth and leaf petioles, hatched in about 1 month.

5. Miscellaneous Insects of Deciduous Fruits. The sex ratio for the Vincennes, Ind., laboratory culture of Trichogramma minutum was established at 56 males:44 females. Progeny, living to adulthood, averaged 30.1 per female. Thus, the culture had the reproductive potential for a 17-fold increase per generation with an average of 10 days per generation.

At Vincennes exposure of 2-day-old red-banded leaf roller eggs to 0° F, 57% relative humidity for 2 to 7 hours killed leaf roller embryos but did not materially affect successful parasitization by Trichogramma minutum.

Survival of Trichogramma at Vincennes under cold storage conditions was improved by holding parasitized red-banded leaf roller eggs at 50° F and 88 to 100% relative humidity. However, the parasites tended to emerge prematurely in the cold storage boxes if held at room temperature more than 3 days before placing in storage. There was no emergence in the cooler at the end of 1 month from eggs that had been parasitized 1-3 days before storage. However, there was 15 to 60% emergence in the refrigerator from eggs that had been parasitized 4 to 7 days prior to cooling. The 1- and 3-day-old group had 64 to 78% emergence when returned to room temperature, with no apparent irregularities in sex ratio, behavior, or searching ability.

At Fort Valley, Ga., newly emerged shot-hole borer adults caused serious damage to peach buds in orchards near unburned piles of bulldozed peach trees. Maps made of the injury patterns in orchards surrounding the infestation source showed that migration occurred readily across open fields for at least 0.2 mile but that little migration occurred through woods.

Progress was made at Wooster, Ohio, in developing a rearing method for blueberry maggot; 546 third-generation puparia were obtained in insectary conditions from a culture of 80 overwintering puparia using fresh blueberries as the food media.

Yellow-colored sticky boards caught significantly more adult walnut husk flies at Wooster than green boards similar in color to immature black walnut husks.

Grape berry moth pupae were held at a constant 40° F in the Wooster laboratory for over 18 weeks without significantly decreasing the time required for adult emergence or increasing pupal mortality. This offers an improvement over the previously-used technique of storing pupae overwinter under

outdoor conditions. Virgin female grape berry moths, placed within sticky tubs, attracted male moths of the overwintering generation.

Female apple maggot adults deposited more eggs in paraffin domes in the laboratory at Wooster when a section of fresh apple was placed under the dome.

At the University of Maine in research under a grant, yellow sticky board traps were three times as attractive to apple maggot flies as red or blue sticky boards or liquid bait mason jar traps in luring apple maggots to chemosterilant residues. Apple maggot puparia collected from field infested fruit required a cold period of 90 days at 32° F to break diapause and permit emergence. Many field collected puparia were parasitized by Opius melleus Gahan. Apple maggot laboratory colonies were developed using cull apples for larval food. Adults were held in half-pint cartons, and exposed to apholate, 5 fluoroerotic acid, hemel, and hempa. Hemel was the most promising chemosterilant.

In New York under a grant, a non-diapausing strain of oriental fruit moth was selected for 80° F and 12-hour light. Selections are being made for lower temperatures and for a diapausing strain.

In studies at Brigham Young University under a grant to determine the ecology of mites within pomaceous tree fruit orchards, 60 commercial and 105 abandoned orchards were surveyed to determine the mite fauna. The following phytoseiid mites were identified: Typhlodromus mcgregori, T. occidentalis, T. smithi, T. oregonensis, T. caudiglans, T. cucumeris, T. fallacis, and T. marinus. Also two new species were found and 4 others are likely to be new when positive identifications are made. Tetranychid mites identified were: Bryobia rubriculus-arborea, B. praetiosa, Panonychus ulmi, Eotetranychus willamettei, E. carpini, Tetranychus mcdanieli, T. canadensis, and T. telarius.

Studies at Washington State University, Wenatchee, Wash., under a grant revealed the following characteristics of pear psylla mating behavior: (1) Mating is necessary for the production of fertile eggs. Mating also speeds egg development and increases egg production. Unmated females deposit only a few infertile eggs. Females must mate at least once every 10 days over a period of 60 days for maximum egg production which averaged 664 in these studies. (2) Each male was capable of mating 6 females to full egg capacity under caged conditions. Ratios in excess of 4 males to 1 female reduced egg production, indicating that excess mating interferes with the female's normal activities. (3) Females mated successfully within a few hours after their final molt while males required about 2 days to reach sexual maturity. (4) Males were the aggressors in mating activity; they sought out the females by randomly walking over the foliage. Females remained quiet during the time they were receptive. The duration of copulation varied from less than 1 minute to as long as 3 to 4 hours but usually was less than 20 minutes. (5) Mating of overwintered females in the spring was required before they deposited fertile eggs, even though they copulated readily in the fall. There was no successful storage of sperm by females over the winter.

In Poland (E21-ENT-16) surveys of arthropods in orchards were made and populations of predators, mites, and other pest species determined. Methods for counting mites on field-collected leaves were evaluated. Short term effects of fungicides, ovicides, and insecticides were established against several predaceous and pest species.

In Yugoslavia (E30-ENT-2) the appearance, distribution, and severity of infestation of 5 species of leaf miners was determined. Biological studies of 2 species, Stigmella (Nepticula) malella St., and Lyonetia clerkella L., were undertaken. The effects of 5 insecticides on S. malella and its parasites were determined. Ten species of Eulophidae parasitized this leaf miner.

#### B. Insecticidal and Cultural Control

1. Codling Moth. At Vincennes, Ind., the effect of normal weathering on Shell SD-8447, Niagara NIA-10242, General Chemical GC-6506, carbaryl, and azinphosmethyl after 3 cover sprays was determined by field-laboratory bioassay. Two-hour-old deposits of all treatments were 100% effective against larvae and adults of both codling moth and red-banded leaf roller. GC-6506 was still effective against larvae of codling moth after 22 days of weathering. SD-8447 and azinphosmethyl were effective against larvae of the red-banded leaf roller after 22 days. Only NIA-10242 was effective against adults of either species after 14 days of weathering.

In field-laboratory bioassays at Yakima, Wash., Shell SD-8447 and Geigy GS-13005 both gave 100% mortality of codling moth adults on twigs and larvae on fruit for five weeks after application. Both materials compared favorably with the standard treatment of azinphosmethyl.

2. Orchard Mites. At Kearneysville, W. Va., further tests with polyflavonoids confirmed earlier findings that these materials may act as mite suppressants. Iron polyflavonoid was the most active of the group tested; however a combination of all of the metallic polyflavonoids (Fe., Mg., Mn., Zn., and Cu.) was more effective than iron polyflavonoid alone. Foliar applications of these materials may fit into an integrated control program if their effect on predatory mites proves minimal.

In laboratory screening tests at Vincennes, Ind., ENT-27,375, ENT-27,552, ENT-27,320, and ENT-27,405 gave 95-100% control of spider mites 7 days after foliar application. ENT-27,405 also gave 100% control when used as a systemic treatment.

In orchard tests on apples at Yakima, Wash., Azodrin, ENT-25,962, and ENT-27,226 gave excellent control of McDaniel and European red mites with two applications during the season. ENT-27,323 and ENT 27,323-X gave good control of mites but were phytotoxic.

At Wooster, Ohio, the following spray materials and spray schedules gave acceptable control of European red mite on Concord grapes: Dicofol combined with the regular grape spray schedule in the prebloom, petal fall and 1st cover sprays; or a dormant spray of 2% Superior-type oil, either 60 or 70 viscosity; or the addition of azinphosmethyl to the regular petal fall, 1st, and 2nd cover grape sprays.

In Israel (A10-ENT-13) strains of the carmine spider mite highly resistant to malathion were found. Preliminary studies suggested that the level of resistance in the mites was positively correlated with nitrogen levels, and negatively correlated with phosphorous levels in the host plants.

3. Pecan Insects. At Albany, Ga., duTer applied at 0.4 and 0.8 active ingredient/100 gallons gave effective control of the spider mite, Eotetranychus hicorniae, but was ineffective against the black pecan aphid.

At Shreveport, La., ULV azinphosmethyl applied by airplane with a micron air system at the rate of 2.6 pounds active/acre gave as good control of the nut casebearer as the same material applied at the rate of 1 pound active in 5.5 gallons of water/acre.

4. Miscellaneous Insect Pests of Deciduous Fruits. At Fort Valley, Ga., only EPN, parathion, and azinphosmethyl, of the currently recommended insecticides, performed well against the plum curculio on peaches. Performance of dieldrin was poor. Carbaryl was effective only when synergized with piperonyl butoxide. Mevinphos was more effective than carbaryl at zero day residue. GC-6506, GS-13005, NIA-10242, SD-8447, and Imidan were the most promising new insecticides.

Insecticide and insecticide-oil combinations applied in the fall at Fort Valley for control of encrusted white peach scale were largely ineffective. Only NIA-10242 with 2% superior oil showed any promise.

In Yakima, Wash., tests with UC-21149 granules, for control of pear psylla, 20 or 40 ounces per tree applied to the root area and soaked into the soil gave effective control for the entire season.

Yakima tests with "Superior" type oils of various viscosities; applied at a concentration of 2% during the delayed dormant period gave the following mortalities of San Jose scale: 90 vis., 99.5%; 80 vis., 97.4%; and 68 vis., 98.6%. A count of scale before spraying showed 85% alive.

At Kearneysville, W. Va., NIA-10242 was the most effective of 3 materials tested for control of the lesser peach tree borer.

At Wooster, Ohio, bait sprays to control apple maggot in a backyard orchard for the past 3 years have reduced infestation to a trace; adult flies were caught on sticky board traps in limited numbers.

At Wooster 2 sprays of carbaryl gave effective control of eriophyid mites on butternut leaves; the sprays were applied 8 days apart, when leaves were about half developed. The addition of malathion to the carbaryl gave no advantage.

At Wooster a single application of lindane gave good control of the hickory gall aphid when the spray was applied at the time the hickory buds were swelling.

In studies at Wooster the presence of walnut husk maggots in the husks of black walnuts did not appear to influence the weight, nor the quality, of the nut kernels.

#### C. Insecticide Residue Determinations

1. At Wooster, Ohio, laboratory studies indicated that Primary Food Color FD 7 C Red #2 (amaranth), used in water alone or in a mixture with insecticides and fungicides, offers a good indicator for comparative studies of spray deposits on glass plates and glass marble rosettes. Amounts of spray deposits were determined by colorimetric methods in studies of various types of experimental sprayers for grapes.

#### D. Biological Control

1. Codling Moth. At Vincennes, Ind., periodic releases during July and August, 1966, of Trichogramma minutum at the rate of about 100,000 parasites per week into 2 apple trees resulted in a reduced number of second-brood codling moth larvae in the fruit of treated trees, as compared to nearby untreated trees.

Studies at Vincennes indicated that codling moth larvae, infected with granulosis virus when the larvae were 15 days old, produced the highest yield of virus particles at the time of larval death. Age groups of 1, 5, 10, 11, 15, 18, and 20-day-old larvae were tested.

2. Orchard Mites. In observations at Yakima, Wash., in 2 apple orchards receiving little or no seasonal insecticides, McDaniel mites built up to their highest economic levels in July but were practically eliminated by the predaceous mite, Typhlodromus occidentalis, by August. Observations on the distribution within trees of Typhlodromus mites in relation to McDaniel mites showed that the latter tended to concentrate in the center of the trees at the start of the season and migrated to the outer portions of the trees during the second and third generations. Migration of Typhlodromus followed the same pattern but lagged behind, giving the McDaniel mite time to cause some leaf injury before the predator arrived and increased in sufficient numbers to be effective.

Research in Poland (E21-ENT-8) demonstrated the high susceptibility of the predaceous mite, Typhlodromus finlandicus, and related species to about 30 pesticides and the depressing effect on predator populations by several seasonal spray programs.

3. Miscellaneous Insects of Deciduous Fruits. Studies at Vincennes, Ind., revealed a very low rate of parasitism of the lesser peach tree borer by larval and pupal parasites. Of 18,638 adult moths collected from caged peach wood in 1966, there were only 50 recognized parasite adults collected, for a parasitism rate of 0.27 percent. The American plum borer was present in lesser numbers (841 adults), with a higher rate of parasitism (5.5%) by the larval parasite, Idechthis nigricoxalis (Devorgilla sp.). The 20-fold differential in parasitism of these 2 peach-boring insects may account, in part, for the greater pest potential of the lesser peach tree borer.

At Yakima, Wash., parasitism of wolly apple aphid by Aphelinus mali reached a peak of 63% by early October 1966 in a 15-acre experimental apple orchard receiving sterile male releases in lieu of insecticides for control of codling moth. Although this important parasite has declined in recent years with the widespread use of insecticides, these observations demonstrate that it is capable of rapid recovery in the absence of insecticide treatments.

At Fort Valley, Ga., several nematode parasites of the genus Neoaplectana were taken from field-collected peach tree borer cocoons.

In studies at Ohio State University under a grant, overwintering mite eggs on trees receiving a commercial spray schedule numbered 1,174 eggs per foot of twig compared to 20 per foot for trees on an integrated spray program. Several species of mite predators were common on trees in the integrated program. Aphids were also controlled by predators in trees receiving the selective insecticides. However, predators did not provide significant control of codling moth, Carpocapsa pomonella (Linnaeus), apple maggot, Rhagoletis pomonella (Walsh), plum curculio, Conotrachelus nenuphar (Herbst), or green fruitworms.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Codling Moth. Control of codling moth by release of sterile moths continues to show promise. In 1966 sterile male moths were released in a 15-acre block within a 500-acre commercial orchard at Yakima, Wash. Sex attractant traps indicated an average ratio of 270 released male moths to each native male. At harvest, 0.038% of the apples from the release plot were infested with codling moth larvae, compared to 0.077% infestation in nearby blocks treated with conventional insecticides.

In 1967 a mixed-sex release of sterile codling moths was initiated in a 93-acre plot near Yakima. A sterile:native moth ratio of about 40:1 has been maintained. As of July 1, codling moth control in the release orchard was equal to or better than that in orchards treated with pesticides.

The codling moth infestation in apples in a 29-tree semi-isolated orchard near Yakima was reduced from 50% in 1965 to 2% in 1966 through release of mixed sexes of irradiated moths after a single pre-release treatment with parathion to reduce a suspected high population of overwintering moths.

In other Yakima studies, female codling moths treated with 30 and 60  $\mu$ g of metepa and mated with untreated males laid 0.2% and 0% viable eggs, respectively. Untreated females mated with males treated with 30 or 60  $\mu$ g of metepa laid no viable eggs. A normal number of matings occurred in each experiment.

Evaluation of the codling moth sex pheromone by Yakima personnel in field cage facilities at Brownsville, Tex., revealed the following: (a) Moth catch per trap (100 1-gallon paper traps/acre) increased as pheromone on blotter paper was increased from 100 to 1,000 to 10,000 female equivalents of extract, (b) trap density (100, 50, 10, 2 traps per acre) of traps baited with 1,000 female equivalents of pheromone did not greatly influence moth catch per acre or number of matings per female, (c) the percentage of mated females increased as the ratio of males:females increased as follows: 1:9, 23%; 1:3, 48%; 1:1, 62%; and 9:1, 81%.

2. Peach Tree Borers. At Vincennes, Ind., sixty 4-vane sticky traps, each containing 6 virgin female lesser peach tree borers, were placed for the second year in the 45-acre Patoka, Ind., peach orchard on April 20. A total of 6,408 virgin females were used during the period, April 20-June 30, 1967, during which time 1,150 native males were captured. At a comparable time in 1966, a total of 3,420 females were placed in traps and 1,514 males were captured.

Marked males were released in the center of the 45-acre peach orchard at Patoka to determine the efficiency of the 360 caged virgin females to attract migrant males. Of 120 marked males released on May 27, 75.0% were caught in the traps; 90.1% of 719 males released on June 12 and 78.6% of 728 males released on June 18 were also caught. In releases made at the four cardinal directions from the orchard, 47% of 602 males released at the 1/4-mile distance, 43.1% of 589 males released at the 1/2-mile distance, and 22.5% of 581 males released at the 3/4-mile distance were recovered from the traps in the orchard.

Studies of virgin female lesser peach tree borers, caged in traps and placed in a peach orchard at Vincennes, demonstrated that 1-day-old females were more attractive to males than older females. A few females remained attractive when 9 days old, but most activity ceased after the fifth day.

Lesser peach tree borer males were caught at Vincennes in traps baited with sex pheromone extracts, prepared by macerating virgin female abdominal tips in either acetone, ethyl alcohol, benzene, hexane, or methylene chloride. These extracts were effective in both cage and open-field tests. Present extracts are not as effective as live virgin females and last only a few hours.

3. Pecan Insects. At Albany, Ga., extracts of whole 1- and 2-day-old virgin female hickory shuckworm moths soaked for 3-3 1/2 hours in methylene chloride elicited strong positive responses from several male moths in the laboratory. When the extract was applied to paper strips and the solvent evaporated, responding males ran wildly over the paper strips while beating their wings.

In studies at Texas A&M University, under a grant, pecan weevil larvae were treated with 1, 5, or 10% apholate or irradiated with 500, 2,500, 12,500, or 62,500 r from a gamma cobalt 60 source. Mortality of larvae irradiated at 62,500 r was 48% in 23 days, and 18% or less for the other treatments.

4. Miscellaneous Insect Pests of Deciduous Fruits. At Fort Valley, Ga., male and female plum curculios were exposed to gamma radiation when 0 to 2, 5 to 7, or 10 to 12 days old and the subsequent effects on feeding and longevity were observed: (a) The 2 sexes and the 3 age groups all responded similarly, (b) longevity and feeding were not greatly affected at 2 and 4 kr, (c) at 8, 16, and 32 kr, LT 50's were slightly over 12 days, (d) at 8, 16, and 32 kr, feeding declined sharply 2 to 4 days before mortality began to rise, (e) at 8, 16, and 32 kr, mortality was not appreciable through 8 days, however, at 10 days following exposure, mortality had started to rise sharply and at 30 days it was nearly complete.

At Riverside, Calif., pear psylla males were sterilized when exposed to pear seedlings dipped in a 3% solution of the chemosterilant tepa. An exposure of 2 hr to the chemosterilant was effective. Virgin females mated with the treated males deposited sterile eggs.

At Wooster, Ohio, corn protein hydrolysate (SIB #7), containing dibasic ammonium phosphate, caught 3.8 times as many apple maggot adults as the bait without the ammonium compound.

In studies at the University of California, Berkeley, under a grant, the radiation dose for inducing optimum dominant lethality in the navel orange-worm was 50 kr for pupae and 60 kr for adults. Pheromone traps were useful in evaluating field populations. A methylene chloride extract of excised female abdominal tips elicited typical mating behavior in males. The pheromone was also highly attractive to the meal moth.

Techniques have been perfected for rearing oriental fruit moths at Grand Junction, Colo., under a grant. An estimated 300,000 moths were produced for research investigations. Cost of labor and expendable supplies for rearing amounted to about \$2.66 per thousand moths.

#### F. Evaluation of Equipment for Insect Detection and Control

1. Codling Moth. At Yakima, Wash., male codling moths responded to the female sex pheromone at temperatures below that at which they responded to blacklight emissions. The two attractants were equally effective at normal summer temperatures. Thus, traps baited with the sex pheromone were more effective than blacklight traps beginning at blossomtime and continuing for approximately a month thereafter. Sex attractant trap catches decline during the second half of the growing season while blacklight trap catches remained the same or increased. During the first half of the growing season, combining live females (sex pheromone) with blacklight doubled the number of moths caught at the trap locations. Indications are that one or perhaps both traps capture only a fraction of the moths actually attracted to them.

2. Pecan Insects. At Albany, Ga., a method was developed for mechanically removing most of the unwanted insects from the small pecan insects collected in blacklight traps. Passing the insect collection through a series of sieves and a blower-separator eliminated most of the larger moths and beetles, reducing the sample size by about 80% by weight.

Hickory shuckworm moths marked with fluorescent pigment were released at Albany on several occasions to test efficiency of blacklight traps. In 10 releases, recovery ranged from 0 to 29.3% and averaged 9.7%. Moths were recaptured up to 5 days after release. Moth age and physical condition at the time of release appeared to important considerations in the success of a recovery. In similar release-recapture studies, moths were released inside a 17 x 17 x 21 ft cage covering a tree and 1 light trap near Albany. Recovery ranged from 17 to 60% with an average 29% recovered from 7 releases. Again moths were not recovered after 5 days from time of release.

3. Miscellaneous Insect Pests of Deciduous Fruits. At Wooster, Ohio, minor alterations of an experimental air-blast, concentrate grape sprayer by the Agricultural Engineering Research Division failed to give acceptable visible spray coverage to Concord grapevines trained to the Geneva double-curtain trellis system. However, a "T-shaped" boom, combined with the conventional set-spar boom, gave acceptable visible coverage when used with a hydraulic sprayer at the rate of 200 gal/acre to grapevines trained to the double-curtain system.

The pear psylla, vector of pear decline, showed positive response to black-light under laboratory conditions at Riverside, Calif. A 15-watt BL lamp was more attractive than a self-filtered BLB lamp. Green, cool-white, gold and red fluorescent lamps were less attractive than blacklight. In the field the 15-watt BL lamps failed to attract psylla, however, 32-watt BL lamps attracted numbers approximately equivalent to those attracted to and captured by the standard yellow sticky-board traps.

#### G. Varietal Evaluation for Insect Control

1. At Riverside, Calif., two-spotted spider mite populations on 3 of 30 strawberry varieties were considerably lower than populations on all other varieties. Shasta had the highest mite population.

At Lexington, Ky., under a grant cooperative with Crops Research Division, marked differences in severity of spider mite feeding damage occurred on strawberry varieties and seedling crosses in greenhouse tests conducted at normal daylight periods in the winter. Progeny of crosses between two resistant parents were generally more resistant than were progeny of selfed-resistant plants or resistant X susceptible parents. Proteinaceous extracts from resistant and susceptible varieties of strawberries are being studied to identify the amino acids in the two plants and correlate them with the amino acid requirements of spider mites in artificial diets.

## I. Insect Vectors of Diseases

In detection work in collaboration with regulatory agencies (PPCD, California Department of Agriculture, and County Departments of Agriculture) the peach mosaic vector mite was found in Madera County, 25 miles farther north than previously recorded in the important northern California peach area, and 160 miles north of any known infections of peach mosaic virus.

The effects of pear decline virus vs. pear psylla toxins in pear trees were compared at Riverside, Calif. Healthy pear trees, in a screen cage experiment, after exposure to viruliferous pear psylla from a pear decline-infected orchard expressed symptoms typical of pear decline disease. Trees similarly exposed to nonviruliferous insects from a decline-free orchard remained normal. Exposure to pear psylla was made in 1964 and the vector was eliminated from the cages at the end of 1964 growing season. Growth measurements and tree vigor recorded to 1967 indicates no permanent adverse effects of toxins injected into the pear trees by the pear psylla under the conditions of this experiment which involved moderate psylla infestations on Bartlett pear trees on Oriental rootstocks, the combination considered susceptible to pear decline.

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## CITRUS AND SUBTROPICAL FRUIT INSECTS

Entomology Research Division, ARS

Problem. Insects and mites that attack citrus and subtropical fruits reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase cost of production. There is a continuing need for research to secure biological and ecological information on these pests that will provide a better basis for the development and implementation of insect control methods than that now available, or suggest additional non-chemical approaches to their control. Additional research is needed on biological control agents, including parasites, predators, and pathogens, and on methods for more effectively integrating biological, chemical, and other control measures. Safer, even more effective and economical control procedures that will minimize or avoid objectionable chemical residues and problems associated with residues should be developed. Research on attractants, chemosterilants, sterilization techniques, and genetic methods need increased attention. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires effective low-cost detection methods, processes for destroying insect infestation in fresh fruits and vegetables intended for shipment to uninfested areas, and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. This program is carried on at Beltsville, Md., Honolulu and Hilo, Hawaii, Riverside, Calif., Orlando, Fla., and Weslaco, Tex., in cooperation with entomologists, chemists, and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research and Plant Pest Control Divisions; at Hoboken, N.J., in cooperation with the Plant Quarantine Division; at Mexico City, Mex., in cooperation with the Plant Pest Control Division and with the Dirección General de Sanidad Vegetal of the Mexican Secretaría de Agricultura y Ganadería, and on the islands of Guam and Rota in cooperation with the Territory of Guam, U.S. Navy, and the Trust Territory of the Pacific Islands.

The Federal scientific effort devoted to research in this area totals 25.7 scientist man-years. Of this number, 5.0 is devoted to basic biology, physiology, and nutrition; 3.7 to insecticidal control; 0.7 to insecticide residue determination; 4.4 to biological control; 5.8 to insect sterility, attractants, and other new approaches to control; 3.9 to insect control treatments for commodities regulated by plant quarantines, 0.8 to insect vectors of diseases; and 1.4 to program leadership.

In addition, Federal support of research in this area under grants and cooperative agreements totals 0.9 scientist man-years. Of this total 0.4 is devoted to basic biology, 0.1 to biological control, and 0.4 to insect attractants.

PL 480 research grants include India (A7-ENT-26), Biology of gall midges affecting mangoes with special reference to extent of damage; India (A7-ENT-35), Biology of gall midges affecting citrus plants with special reference to the extent of damage; Egypt (F4-ENT-9), Induced sterility in males of Mediterranean fruit fly as a means of controlling and eradicating that pest.

New PL 480 projects recently initiated include grants for research in India (A7-ENT-47) on biology of gall midges affecting figs with special reference to the extent of damage; and in Israel (A10-ENT-15) on the ecology, biology, and control of the citrus bud mite (Aceria sheldoni, Eriophyidae).

#### PROGRAM OF STATE EXPERIMENT STATIONS

A total of 21.4 professional man-years is devoted to this area of reasearch.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Physiology, and Nutrition

1. Citrus Insects and Mites. Monthly infrared aerial photographs of 6 citrus groves taken at the same time as ground surveys clearly demonstrated population buildups of brown soft scale at Weslaco, Tex. Random infrared aerial photographs of other groves also detected developing brown soft scale infestaitons.

Observations on the fecundity of laboratory reared brown soft scale at Weslaco revealed that one group of scale produced crawlers for 151 days when raised on Mexican squash. Production of crawlers started 45 days after attachment and mean production was 16.3 crawlers per female per day. One individual produced a total 2,399 crawlers during the 21 weeks of its life. During one week (11th) this scale produced 431 crawlers.

Honeydew melons, celery, English ivy, and Cienfuegosia sp. proved effective for laboratory rearing of brown soft scale in Texas, thus adding versatility to rearing procedures in scale and parasite studies.

Citrus trees adjacent to cleopatra mandarin and salt cedar windbreaks had lower populations of the brown soft scale than trees farther out in the grove at Weslaco, Tex. Observations with sticky plates also revealed that populations of the brown soft scale and other citrus insects and mites were similarly influenced by windbreaks on the south sides of the groves. Prevailing winds in the Lower Rio Grande Valley are from the southeast.

At Riverside, Calif., male California red scales in free flight were exposed to various extracts of female sex pheromone in competition with groups of 1, 10, and 20 virgin females on a turntable olfactometer. The most active extracts attracted about 70% of the males responding to all the treatments, and the least active attracted only 1 to 2% of all the responding males. The ratio of male response to the 3 groups of females remained relatively stable. The standard curve obtained from male response to different numbers of virgin females was not altered by the competition from pheromone preparations.

In preliminary tests at Riverside to compare mating response of the laboratory strain of California red scale collected over 30 years ago with that of a recently-collected field strain, males of both strains responded similarly to laboratory female pheromone extracts at dosages of 0, 1, 10, 100, and 1,000  $\mu$ g with 100  $\mu$ g appearing to be the optimum dosage.

Progress was made at the University of California under a grant for research on the use of supplemental foods to increase populations of mite predators. When the predaceous mite, Amblyseius hibisci (Chant), was fed various combinations and proportions of sucrose, yeast hydrolysate, and phytophagous mites, yeast hydrolysate slightly increased oviposition; however, its excess was detrimental to survival and oviposition. Addition of sucrose to the diet greatly increased oviposition and survival over that of prey alone.

Techniques were developed in research at the University of Hawaii, under a grant, for rearing southern green stinkbug and its most effective tachinid parasite. Seventy percent of the stinkbugs in Keeau orchard, 33 to 60% at Kailua, Kona, and 19% at Capt. Cook orchard on Hawaii were parasitized. Several species of weeds that are attractive to stinkbugs have been found. Up to 18% of macadamia nuts were damaged by stinkbug feeding.

In India (A7-ENT-26) the gall midge, Erosomyia indica Grover, the most destructive species on mangoes, was found to attack the preflowering shoots in addition to the floral buds, axis of inflorescence, and the newly-formed fruit. In a related project (A7-ENT-35) Dasineura citri Grover, the most destructive gall midge of citrus in India, was established as a distinct species. Progress was made in a third project (A7-ENT-47) to identify and determine the biology of gall midges attacking figs in India. In studies with a species described as Udumbaria nainiensis Grover, the 4th instar larval exit was triggered by sudden increases in humidity. The 4th instar larvae were able to live for 12 days submerged in water.

2. Subtropical Fruit Flies. In Hawaii, fruits of 9 of 20 plant species collected during the period of June 1966 to May 1967 were infested with more than one species of fruit flies. Cocona (Solanum toapiro) and tomato yielded melon and oriental fruit flies. Mixed infestations of Mediterranean and oriental fruit flies were recovered from coffee, guava, green sapote, peach, rose apple, mango, and papaya.

In Hilo, Hawaii, mating studies, including dissection of females, indicate that at approximately 80° F about 60 minutes in copula are required by

Medflies and 90 minutes for the oriental and melon flies before spermathecae in most females are filled with spermatazoa. Little or no transfer occurs in the first 15 minutes. Several decapitated females retained motile sperm in their spermathecae until dissected 24 to 27 hours later.

At Honolulu, a technique was developed for obtaining eggs for experimental or mass rearing purposes from a large number of individual females in less than one-tenth the time formerly required when eggs were transferred by hand with a brush. For a 24-hour period the mean and maximum rates of egg deposition obtained with the oriental fruit fly, Medfly, and melon fly were 110, 133; 84, 105; and 32, 63, respectively.

Studies at Honolulu showed that the Medfly must have access to sugar soon after emergence, but apparently can do without water for a few days. At 2 to 3 days after emergence, there was 97 to 100% mortality of adults on water diet alone, compared with 2% mortality on sugar alone, and 1 to 2% mortality on diet of sugar plus water. At 5 to 6 days sugar alone gave 18 to 29% mortality, and sugar and water only 5 to 8%. While the adults need water eventually, the critical constituent of the diet for survival is sugar. Dry sugar instead of liquid mixtures may be adequate for sterile flies that emerge in and are released from aerially distributed packages.

At Hilo tests showed that old pupae of the oriental fruit fly, melon fly, and Mediterranean fruit fly can be held in water up to 48 hours without reducing percent emergence or subsequent adult longevity. At 72 hours significant damage to Medfly pupae appeared. During the period in water, development practically ceased and emergence was delayed by the amount of time the pupae were submerged.

At Hilo melon fly traps baited with cue-lure were spaced uniformly over 135 acres at the rate of 1 per 5 acres. About 90,000 sterile melon flies (half males) emerged near the center, 40' from the nearest trap. The earliest male response was at 5 days of age. The peak response occurred at 8 to 11 days at the time most males were reaching sexual maturity. The nearest trap caught no flies and 67% of the total catch appeared in the downwind quadrant confirming earlier evidence that the flies move out from their emergence sites before most of them reach sexual maturity.

In Honolulu conversion from dehydrated carrot powder larval diet to a low-cost diet, consisting of middlings, shorts, sucrose, Torula yeast (developed at the Mexico City Laboratory), Gelgard M, sodium benzoate, Nipagen, HCl, and water, was made in the laboratory for the production of the three species of fruit flies. Nearly 39 million pupae were produced from approximately 60 million eggs. Six liters of the new diet will support 125,000 Medfly eggs and up to 100,000 pupae can be recovered. Unlike with the Medfly and oriental fruit fly, the middling-shorts diet produces a slightly smaller melon fly pupae than the carrot diet. The smaller melon fly will require evaluation in the field for effectiveness in sterile male release programs. Material cost for the production of the Medfly is now approximately \$10.00 per million pupae and for oriental and melon flies about \$16.00.

A Medfly larval diet, developed in Costa Rica and consisting of milled bagasse, torula yeast, sugar, wheat germ, mold inhibitors, and HCl, was evaluated in Honolulu. When wheat shorts and middlings were substituted for milled bagasse and wheat germ, the diet performed equally well, except for the slightly smaller pupae it produced.

At Mexico City in an experimental rearing medium, wheat middlings and granulated sugar was substituted for half of the dehydrated carrots in the larval rearing medium. Larval recovery was about the same as that from the standard formula and showed promise of reducing costs in mass rearing. Wheat shorts obtained locally are about 1/10 as expensive as the dehydrated carrots.

Weekly releases of 60,000 marked, tepa-sterilized Mexican fruit fly pupae at El Cerro provided information on seasonal fly movement between the release point and El Bebedero, Morelos, 2 to 3 miles apart. Released flies were marked with yellow fluorescent dye as they emerged through treated foam rubber. The high catches of marked flies occurred during the peak of wild fly populations from May to July and from December to March, which may signal the start of seasonal fly dispersal.

Mexican fruit fly production in a navel orange orchard of 44.1 acres at Coatepec, Veracruz, for the month of November 1966 was about 62,205.

#### B. Insecticidal and Cultural Control

1. Citrus Insects and Mites. Application of 10% granular UC-21149 to potted citrus at Weslaco, Tex., suppressed brown soft scale up to 17 weeks. Populations on trees treated with 2-, 3-, and 4-gm dosages never reached the level of that on the check tree, which died 25 weeks after the test was started. No evidence of phytotoxicity was apparent from any of the treatments.

A caged citrus tree at Weslaco which was treated with 10% UC-21149 granules showed sharp reductions in brown soft scale (99.5%), purple scale (96.5%), California red scale (85.5%), and chaff scale (90.5%) populations 3 months after treatment. Populations of all 4 species remained at the reduced levels 6 months after they were treated. Parasites remained active in the California red scale and chaff scale populations throughout the observation period.

Applications of methyl parathion at 1/4 lb per 100 gal of water on potted citrus trees increased brown soft scale populations by 69% over the untreated check 10 weeks after treatment at Weslaco. Potted trees treated with methyl parathion at 1 lb per 100 gal produced about the same number of scales as the check, while those treated with 10 ppm of 4,6-dinitro-o-cresol had only 75% as many scales at 10 weeks. Azinphosmethyl and carbaryl, each at 1 lb actual per 100 gal of water, reduced scale 100% and 99.7%, respectively, the second week after treatment. The rapid increase in scale numbers on trees treated with methyl parathion (1/4-lb dosage) demonstrates a

stimulatory effect which first became evident in large scale field tests. These greenhouse studies conducted in the absence of parasites or predators demonstrate that the increases in scale numbers above the check are not related to the suppression of entomophagous species.

In studies at Riverside, Calif., to determine the influence of UC-21149 on the growth and fruiting of young citrus trees by controlling aphids, citrus thrips, and citrus red mite, navel and Valencia oranges and Lisbon lemon trees received 1.25 and 4.5 g active ingredient per tree of UC-21149 in 10% granular formulation, in the water basin a week after planting in April 1966. Eight months after application, the higher dosage produced 100, 99, and 62% control of the spirea aphid on navels, Valencia, and lemons, respectively. Eleven months after application, the higher dosage produced 99, 98, and 89% control of the citrus red mite on navels, Valencia, and lemons, respectively. For the second annual application, 2.5 and 10 g active ingredient per tree was distributed in the water basin on March 1967. Three months later, 88 to 100% control of citrus red mites and 92 to 100% control of citrus thrips was obtained with both dosages in all 3 varieties. UC-21149-treated orange trees were noticeably larger and more vigorous than untreated controls and appeared slightly larger than the trees receiving the foliar application of recommended pesticides. No differences were apparent in the lemon trees.

In other California tests, UC-21149 was applied as a 10% granular formulation in a narrow band in the soil on each side of mature navel orange trees at rates of 0.1 and 0.2 lb active ingredient per tree. During the first one-half year following application, control of citrus red mite was inadequate with only 62% control being obtained with the higher dosage in 5 months. Mite control improved with time, and at 13 months 69 and 96% control was obtained with the 0.1 and 0.2 lb dosages, respectively.

At Orlando, Fla., soil applications of UC-21149 at 1 or 2 oz of granules per inch of trunk diameter controlled citrus rust mites and citrus red mites through 12 weeks and showed no signs of failing.

2. Subtropical Fruit Flies. Bioassay studies with Mexican fruit flies at Weslaco, Tex., showed that the 1:4 technical malathion-PIB-7 formulation used in the Brownsville Mediterranean fruit fly eradication program was residually effective for 9 days under southern Texas climatic conditions. Deposits from aerial applications on citrus, oleander, and bougainvillea foliage showed evidence of slight variation in comparative performance on leaves of these plants.

Examinations of the spermathecae of the last six female Mediterranean fruit flies collected in Brownsville revealed that only one contained sperm. This fly, which was trapped 26 days after the first Medfly found, was the last fertilized female collected and demonstrates the effectiveness of the bait spray applications in Brownsville.

Technical malathion-PIB-7 at ratios of 1:4; 1:20, 1:100; 1:1,000; and 1:10,000 without water were tested as bait spray (1 ml to foliage over

traps) against the Mexican fruit fly. The 1:4, 1:20, and 1:100 formulation attracted and killed the same number of flies at 1, 6, and 14 days after application.

Bait sprays with technical malathion-PIB-7 (1:4) against the Mexican fruit fly were started in January 1967 in 31 acres of navel orange trees at La Orduna, near Coatepec, Veracruz, in the center of a very extensive citrus area. The sprays were applied weekly with a standard Hudson knapsack sprayer to every other tree (alternated each week) whenever possible at the rate of 1.31 oz/acre of technical malathion or 6.70 oz of mixed spray per acre. The 7.2-acre check grove is separated from the 5.6-acre test grove by 8 rows of trees. Collections from 50 traps placed once a month on every other tree in the center of the treated and check areas for a period of 1 week showed a decrease of 84 to 98% in Mexican fruit fly population in the test area over that in the check. Fruit fly infestations per kilo of samples collected in May from tree and ground fruits were reduced by 86.2% and 96.2%, respectively, as compared with the check fruit.

In laboratory tests at Honolulu, Hawaii, small droplets of mixtures of 1 part 95% technical malathion or naled with 8 parts PIB-7 blistered or pitted acrylic and nitrocellulose lacquer and acrylic enamel automobile finishes after 1 hour exposure in sunlight. Mixtures of 0.1 part malathion or naled in 8 parts bait, however, left only light stains easily removable with a mild liquid cleaner, even after exposures of 4 hours.

The laboratory strain of melon flies, bred since 1958 at Honolulu, on artificial non-toxic media, was found to have become highly resistant to standard DDT topical treatments (1 microliter acetone solution applied to the dorsal thorax) without selection with DDT. Applications made up to the limit of solubility in each instance failed to produce significant mortality. The resistance was less when treatment was applied on other body parts. In evaluations prior to 1959, the melon fly appeared only a little more tolerant of DDT than the other Hawaiian species. Both the present oriental fruit fly and melon fly laboratory strains showed a 4-fold increase in resistance to chlordane, but the Medfly showed no change. No increase in resistance to malathion has occurred in any of the 3 species during the past 13 years. Wild melon flies, collected on the island of Hawaii, were also found to now be highly resistant to DDT applied topically to the dorsal thorax, i.e. no LD-50 or LD-95 could be achieved with saturated solutions.

#### C. Insecticide Residue Determinations

1. Citrus Insects and Mites. At Riverside, Calif., UC-21149 was applied to the soil around orange trees at rates of 0.09, 0.45, and 2.26 g of active ingredient per square foot. Analysis by Pesticide Chemicals Research Branch chemists at Yakima, Wash., of the orange peel and pulp approximately 100 days after treatment showed no UC-21149 residues present. However, residues of the sulfoxide of UC-21149 in the peel from the 3 treatments were 0.06, 1.39, and 12.75 ppm, respectively, and the residues in the pulp were 0.03,

0.35, and 2.63 ppm. Residues of the sulfone of IUC-21149 in the peel were 0.01, 0.36, and 2.24 ppm, and those in the pulp were less than 0.01, 0.13, and 0.58 ppm.

2. Subtropical Fruit Flies. In Honolulu, Hawaii, residues of malathion on tomatoes were 0.12, 0.16, and 0.36 ppm after 0, 1, and 3 days, respectively, from air application of an ultra low volume bait spray mixture of 1 part 95% technical malathion and 4 parts Protein Insecticide Bait No. 7 at a rate of 4 oz toxicant per acre.

In Honolulu inorganic bromide residues in papayas packaged in fiberboard boxes were 11.3 ppm at 1 day and 13.1 ppm at 3 days after fumigation at 70° F with methyl bromide for 3 hours at the dose of 2 lbs/1,000 ft<sup>3</sup> and refrigeration at 55° F after 2 hours of aeration. The residues were 17.5 ppm at 1 day and 15.0 ppm at 3 days after fumigation at 4 lbs/1,000 ft<sup>3</sup> for 3 hours at 70° F. Methyl bromide was not detected at the dose of 4 lbs.

3. Analytical Equipment. A method was developed at Hoboken, N.J., for field-checking the calibration of thermal conductivity gas analyzers. At 68° F or above, a small amount of carbon tetrachloride, accurately measured in a hypodermic syringe, is added to a 1-gal jug. After a 2-hr waiting period to insure complete vaporization, the maximum reading is determined on the thermal conductivity unit. The quantity of carbon tetrachloride added to obtain a given reading varies with temperature.

#### D. Biological Control

1. Citrus Insects and Mites. Observations on parasitism of brown soft scale at Weslaco, Tex., revealed that parasite population trends generally followed the pattern of the previous year. Coccophagus lycimnia again constituted in excess of 90% of the parasites collected. The appearance of parasites throughout the cotton spraying season may be related to widespread use of ultra low volume applications of methyl parathion which may cause less drift into citrus groves. A mean of 2.5% of the scale collected in the Rio Grande Valley during the year were found to be parasitized.

Six species of brown soft scale parasites were introduced from California and released in Rio Grande Valley citrus groves and in tree cages during the year. These were: Encyrtus lecaniorum and Metaphycus stanleyi (currently being reared in the insectary), Metaphycus luteolus, Coccophagus cowperi, C. scutellaris, and Diversinervus elegans. First generation offspring of E. lecaniorum and M. luteolus were recovered but to date no additional recoveries of the introduced species have been made.

Laboratory studies at Orlando, Fla., showed that the citrus red mite virus can be transmitted to the Texas citrus mite. Efficiency of the virus against the latter was equal to that against the citrus red mite. Transmission tests against the citrus rust mite were negative.

In temperature studies at Orlando the entomogenous fungus, Entomophthora floridana, survived for 168 hours at a temperature of  $-20.5^{\circ}\text{C}$ . When Texas citrus mites killed by E. floridana were held in the freezing compartment of a refrigerator and later removed and placed in a favorable environment, the fungus formed conidial haloes around the mite bodies. Diseased dead mites subjected to temperatures of from  $-2.2^{\circ}\text{C}$  to  $0^{\circ}\text{C}$  for 7 hours, followed by 17 hours at temperatures of from  $3.3^{\circ}\text{C}$  to  $6.7^{\circ}\text{C}$  also produced normal conidial haloes. Texas citrus mites placed in contact with conidia from these tests became infected with the fungus, indicating that the pathogen can tolerate low temperatures.

Aphytis holoxanthus, a species introduced a few years ago, has practically replaced Pseudhomalopoda prima as the dominant parasite of the Florida red scale and is holding scale populations at extremely low levels. A survey of 104 commercial citrus groves throughout the citrus producing area of Florida from February 20 to June 8, 1967, showed that Florida red scale did not occur in economic numbers in any of the groves sampled. Formerly, this pest was the number 2 armored scale problem in Florida.

In tests at Riverside, Calif., to determine residual persistence of the citrus red mite virus, the pathogen remained infective to healthy mites for 28 days on lemon fruits that had been fed on for 24 hours by infected mites. Over 60% infection occurred in mites feeding on the inoculated fruit during the first 8 days; the virus was transmitted for 28 days.

In other tests, pH and salt concentration were shown to play an important part in inactivation of virus suspensions. Inactivation was proportional to salt concentration under neutral and alkaline conditions, but no effect from salt concentration occurred under acidic conditions.

The noninclusion virus of the citrus red mite was further evaluated in the field at Riverside and vicinity through modifications in application and closer scrutiny of mites after application. Buffered and unbuffered distilled water suspensions (0.1%) of triturated diseased mites, both at pH 6, were sprayed onto infested orange trees. During the 2 months following treatment, the incidence of diseased mites on trees sprayed with the buffered suspension was 5 times greater than in the untreated controls and 3 times greater on those sprayed with the unbuffered suspension than in the controls. Applications of virus sprays to mite-infested trees in the morning or after sundown to determine possible ultraviolet inactivation of virus showed no difference in infection and both produced 6 times greater incidence of disease than the untreated controls during the 6 weeks following application. Laboratory reared, virus-infected citrus red mites were released on lemon trees and compared with transfer of field-infected mites from an epizootic. During the next 3 months, the incidence of disease was 8 and 21 times greater in trees receiving the laboratory reared and infected mites and those receiving the field-infected mites, respectively, than in the untreated controls. All tests resulted in eventual epizootics with the incidence of disease in the controls and nontest trees becoming as high as the treatments.

2. Subtropical Fruit Flies. Three species of parasites were recovered from pupae of the Caribbean fruit fly, Anastrepha suspensa, at the University of Florida in studies under a grant. These included Pachycrenoideus vindemiae (Rond.) and Opius sp. The third species has not been identified. An anthocorid, Xylocoris galactinus (Fieber) was observed feeding on fruit fly larvae.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Citrus Insects and Mites. Olfactometer studies at Riverside, Calif., showed that California red scale sex pheromone extracts from a homogenate of 180,000 females contained 0.19 equivalents of attractiveness when compared with live virgin females. By contrast, extracts from a cold trap condensate representing pheromone from 62,500 source females ( $1 \times 10^6$  female day equivalents) contained 1.34 equivalents of attractiveness. The yield of the latter was 7 times that of the whole body extractions.

Female sex pheromone of the California red scale collected as a cold-trap condensate and as extracts of homogenized whole females at Riverside are being shipped to the Natural Products Investigations Unit of Pesticide Chemicals Research Branch, Beltsville, Md., for purification, identification, and eventual synthesis of the pheromone. Of the fractions returned to Riverside and bioassayed for male response, 3 were highly attractive and their properties indicate the pheromone to be an unsaturated ester containing at least 2 double bonds.

At Riverside a pooled ethereal extract of the California red scale female sex pheromone obtained from a cold-trap condensate and homogenized whole females was placed in a shallow dish of sand and exposed to males in free flight after various intervals to determine residual activity. A 1,000  $\mu$ g dosage remained as attractive as 10 virgin females for 2 weeks and still retained some activity after 34 days. The lipids in the extract derived from the homogenized females are believed to be acting as extenders. Myverol a monoglyceride of lard, acted as an extender of an extract of cold trap condensate alone.

In studies undertaken at Weslaco, Tex., to sterilize brown soft scale by irradiation as a medium for releasing parasites in citrus groves without adding to the biotic potential of the natural scale population, the age at which the scales were irradiated was critical in inhibiting reproduction in this parthenogenetic species. Irradiation of either sexually mature or 25-day-old scales severely limited but failed to stop crawler production. Scales that were irradiated at an earlier stage of development produced no crawlers at dosages of 20,000 and 40,000 r in a previous test. Since scale populations do not develop uniformly, the precise timing of the irradiation treatment required to provide complete suppression of crawler production is difficult to accomplish.

2. Subtropical Fruit Flies. Fourteen of 17 materials screened for attractancy to the fruit fly, Anastrepha suspensa, in Miami, Fla., were equal to casein hydrolysate when tested on sticky board traps. Glass traps with liquid protein hydrolysate baits were significantly more effective in trapping A. suspensa than were sticky traps baited with protein hydrolysates.

In Hawaii 3 methods of distributing trimedlure-dibrom were evaluated on non-replicated 1/4 x 1/4 mile plots in tests against male Mediterranean fruit flies where sterile flies had been released twice weekly in the sea-level area to obtain uniform populations under high temperature conditions. Three biweekly liquid aerial applications in lines 300' apart resulted in reductions in male trap catches of from 89 to 98% one day after application, but generally lost effectiveness within 5 days. Eighty 2" x 2" bait stations added 3 times at 3-week intervals (1 per 2 acres) gave reduction of 73 to 95% at 5 to 15 days after the first 2 applications. Saturated small wafers, totaling 12 per acre in 3 biweekly applications, gave reductions of 56 to 93% at 1 to 5 days after application. In the third and fourth weeks after the 3 applications of each treatment, catches per trap day averaged 48, 3, and 6, respectively, for liquid aerial applications, bait stations, and wafers.

In Hawaii, male, lure-toxicant formulas and methods of exposure were continued using replicated trays usually suspended under treated foliage or bait stations. Trimedlure-saturated wafers exposed 100 days on shaded soil were equal to freshly saturated wafers when suspended as bait stations. Bait stations or cane-fiber board wafers saturated with trimedlure killed 5 times as many flies for 2 months when suspended in the open over trays as when lying on the ground where flies were subject to ant predation.

A cooperative effort, supported jointly by the Honolulu station, U.S. Air Force, and Portuguese Azores, was undertaken on the 240 mi<sup>2</sup> island of Terceira to complete a feasibility trial of trimedlure-naled applications for control of the Nedfly by the male annihilation method. Aerial applications at the rate of 5 lb of the lure formulation/km<sup>2</sup> containing 5.75% CAB-O-SIL, 5% naled, and 89.25% medlure or trimedlure were first used. Bait stations, made of 2 x 2 x 1/2" cane fiberboard squares, saturated with the lure-toxicant mixture were interspersed at the rate of 3,500 per month for 3 months with the foliar treatments and later replaced some of them. Male catches were substantially reduced in all treated host areas.

Tests were continued in Honolulu to improve the residual effectiveness of foliage deposits of male lure-toxicant-thickener mixtures, particularly those containing trimedlure, which usually become ineffective within 3 or 4 days. Preliminary tests in which different thickening agents and toxicant formulations were used with trimedlure, indicate that deposits containing naled CS-5891 and Myverol 1800 may be effective up to 2 weeks.

Approximately 4 and 6 million sterile melon flies were shipped from Honolulu to Rota, Mariana Islands, between September 15 and November 24, 1966, and between March 30 and July 6, 1967, respectively, to eradicate

the fourth and fifth reintroductions of the melon fly from Guam. Nearly half of the 1967 shipments were of a dark, easily identifiable strain sent for field evaluation. It was recovered in survey traps at only half the rate of the 10-year-old standard laboratory strain.

In Hawaii, newly emerged female Medflies irradiated at minimum doses of 5 and 7.5 Kr, then paired with normal males, did not lay any eggs, but 6-day-old virgin or non-virgin females treated similarly laid many nonviable eggs. At the 7.5 Kr dosage, a mean hatch of 2% was obtained from pairings of normal females with males irradiated shortly after emergence, whereas 0.1 and 0% mean hatch figures were obtained from normal females paired with males irradiated as 6-day-old mated and 6-day-old unmated flies, respectively.

In Honolulu tepa-sterilized flies were more resistant to topical applications of malathion than normal flies. The amount of malathion required to achieve the LD-50 level of mortality was increased 1.38, 1.72, and 2.37 times, and for the LD-95 level, 1.30, 1.62, and 2.28 times in the tests with chemo-sterilized oriental, melon, and Mediterranean fruit flies, respectively, compared with normal flies. Further tests indicated that all three species, when sterilized by ionizing radiation, also became more resistant to malathion and to a greater extent than those sterilized with tepa. For example, at the 50% mortality level, the oriental fruit fly required 1.71, the melon fly 1.71, and the Medfly 2.23 times as much malathion when sterilized by ionizing radiation, respectively, as untreated flies. At the 50% mortality level, the oriental fruit fly required 3.95 and 8.35, and the Medfly 2.35 and 3.38 times as much DDT when sterilized by tepa or ionizing radiation, respectively, as untreated, non-sterile flies.

No adverse effects from the use of Day-glo fluorescent powders as compared to Calco oil soluble dyes for marking released flies were found in tests at Honolulu. The oriental fruit fly, the Medfly, and the melon fly were marked with Day-glo fluorescent powders Rocket red, Signal green, and Horizon blue, and the Calco blue (RA) standard. Possible adverse effects were determined by comparing survival rates for 4 weeks. Studies of dye transfer from marked to unmarked tephritids caught together in dry traps have shown that this hazard is negligible under field conditions. No difference in mortality rates occurred in the first 3 weeks after emergence.

Paper bags (12-1b) containing excelsior and food (such as are being used in a Medfly eradication program in Central America as a means of aerially dispersing Medflies allowed to emerge inside) were tested at Honolulu for their effect on the flies. Placement of food on the excelsior reduced mean survival rates 3 weeks after release nearly 50% compared to food placed on the wicks. Loading rates affected mortality. It ranged from 2.5% in controls to 4, 6, and 8% at 2,500; 5,000; and 10,000 loading rates, respectively. Survival at the 10,000 rate at 3 weeks averaged 21% compared to 38% at the 2,500 rate.  $\text{CO}_2$  concentrations reach 10x normal.

In Honolulu, 15 samples of trimedlure-extender mixtures, prepared by the chemists at Beltsville, were tested on wicks to determine increased persistence of attraction as compared with trimedlure alone. None of the samples tested enhanced the degree of attractancy of trimedlure, nor was there any depression. However, all extended the duration of attraction at least 20% over that of trimedlure with no additive.

Standard trimedlure traps in a 15-replicate experiment, exposed at various heights, caught significantly more flies (70 to 80%) at 15' than at the 0.1 and 2 ft levels. The catch at 15' was 30% greater than at 6', but this difference was not statistically significant.

In a field test in the state of Morelos, Mexico, releases of sterilized, well-fed adult Mexican fruit flies which had been allowed to emerge in the laboratory, consistently showed a higher incidence of mated females when examined microscopically than flies which had been released as pupae from pupal release stations. It is possible that the laboratory feeding may help the flies released as adults to attain sexual maturity sooner than those released as pupae when conditions in the field are not optimal. Preliminary data indicate that at certain seasons of the year when conditions are better, the flies from both adult and pupal releases will attain sexual maturity at about the same time and show about the same incidence of mated females.

At Mexico City, flies from pupae treated with a sterilizing dosage of tepe (5% for 1 minute) were forced to emerge through a 1.5 capping of grated foam rubber impregnated with an 8% concentration of dye. Results showed some loss of sterilizing effect in both males and females.

In olfactometer tests of 125 ENT candidate attractants at Mexico City, one proteinaceous material and three Sargentia greggii fruit extracts attracted the same number of Mexican fruit flies as the standard. Sixty-eight other compounds attracted flies but to a lesser extent than the standard cottonseed hydrolysate.

Of 158 candidate lures field-tested in McPhail traps in the state of Morelos, 2 ENT candidates, a Sargentia greggii extract and a terpene of grapefruit oil, were about 1.5 times more attractive than the standard cottonseed hydrolysate-borax lure in pellet form (Class 5). Twenty-four compounds were 0.25 to 1.00 as attractive as the standard (Class 1 to 4) and 131 attracted no flies.

An enzyme hydrolyzed meat protein fermentation nutrient (0.M. HAP) was 65% more attractive than cottonseed hydrolysate-borax pellets (0.20:1) when tested in solution at 2% with 2% borax. A disadvantage of this material is that it attracted 2.9 times more muscid flies than the standard.

Three replicates of 1, 2, 4, 8, and 12 traps baited with cottonseed hydrolysate borax pellets were exposed in mango trees for 5 days to determine the number of traps per tree needed to capture the maximum number of

flies. The results indicated that more than 12 traps can be used, and that there may be little or no competition between traps.

#### G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. In Honolulu, Hawaii, the minimum period of post-treatment refrigeration at fruit temperatures of 45° and 55° F were determined with infested papayas for fumigations at 70 + 1° with methyl bromide. The dose was 2 lb/1,000 ft<sup>3</sup> for a 35-lb load of fiberboard boxes with shredded paper excelsior that occupied 44 ft<sup>3</sup> in the 100 ft<sup>3</sup> chamber. There were no survivors for the 3-hr fumigation treatment followed by 3 days at 45° or 6 days at 55°.

In Honolulu, the hot water dip for controlling decay organisms reduced the survival of eggs and larvae of the oriental fruit fly from papayas that were fumigated with methyl bromide for 2 hours at 70 + 1° F at the dose of 1 lb/1,000 ft<sup>3</sup> when the dip treatment was given before or after the fumigation. There were no significant differences between fruits that were treated while hot and those that were cooled to 70° before treatment. There were no significant effects from fumigation with ethylene dibromide at the doses of 4 and 8 oz/1,000 ft<sup>3</sup> for 2 hours.

In Honolulu the development of 2- to 5-hour-old eggs and mature third-instar larvae of the oriental fruit fly were arrested after treatment in hot water. The minimum treatment periods for the eggs were 60 minutes at 110°, 14 minutes at 115°, 3 minutes at 120°, and 0.25 minute at 130° F.

In Honolulu the minimum treatment periods with hot water found effective for mature larvae of the oriental fruit fly in tomatoes were also effective in limited testing with melon fly infestations at pulp temperatures of 110°, 115°, and 120° F. Forty-five to 115 minutes were required to raise the pulp temperature from 70° to treatment temperature. Treatments with temperature run-up to 120° only killed most of the infestations but when the run-up was supplemented with the minimum treatment of 5 minutes at 120°, there were no survivors.

At Mexico City, mangoes infested with Mexican fruit fly were maintained for 3 and 6 days at 35° F. and then fumigated with 2 lb of methyl bromide/1,000 ft<sup>3</sup> for 2 and 3 hours at 34°, 35°, and 40° F. Mortality varied from 63 to 93%; the optimum treatment was 6 days at 35° F. followed by 3 hours of fumigation at 34° F. Mangoes did not tolerate methyl bromide well. Whether this injury was due to the small amount (2%) of chloropicrin in the fumigant was not determined.

Treatment of infested mangoes with 125 tablets of Phostoxin (aluminum phosphide 70%, ammonium carbamate 26%, and other ingredients 4%)/1,000 ft<sup>3</sup> required about 4 days exposure at 70° F. to obtain 100% mortality. At 1 and 2 days exposure the mortality was 95.4 and 99.4%, respectively. At these dosages and exposure periods the fruit were injured.

Larvae of Anastrepha serpentina in the first to second instar in carrot medium were completely killed with 8 oz of ethylene dibromide/1,000 ft<sup>3</sup> at 75° F. Third instar larvae, naked and in carrot medium were killed with 16 oz of ethylene dibromide/1,000 ft<sup>3</sup> at 75° F.

Infestations of the Mexican fruit fly in mangoes were fumigated at 70° F with methyl bromide alone and mixed with ethylene dibromide. The mortalities for methyl bromide varied from 2.7 to 87.6%. Mortalities for mixtures of methyl bromide and ethylene dibromide were approximately the same as for ethylene dibromide alone. Methyl bromide above 8 oz injured mangoes severely. Whether injury was due to the 2% of chloropicrin included in the methyl bromide was not determined. To kill 100% (probit 9) of naked full grown larvae required 16 oz of methyl bromide and 2 oz of ethylene dibromide.

2. Other Insects. In preliminary tests at Hoboken, N.J., fumigation with 270 aluminum phosphide pellets per 1,000 ft<sup>3</sup> for 72 hr at 80° F or above failed to give 100% control of Megastigmus spp. larvae in Picea seeds. Small numbers of Plemeliella abietina larvae were killed at this dosage. In other tests, seeds of Picea abies, P. sitchensis, Pinus mugo, and P. sylvestris showed no injury when germinated shortly after fumigation at this dosage.

Fumigation in a saturated atmosphere of carbon tetrachloride (near 58 lb/1,000 ft<sup>3</sup>) at Hoboken caused severe injury to seeds of Pinus mugo and Picea glauca, even with exposure shortened to 4 hr. In other tests Pinus pinea and Cedrus deodara seeds were injured by 8- and 16-hr exposures.

At Hoboken germination tests shortly after fumigation with Vertifume (carbon tetrachloride-carbon disulfide, 5:1 by weight) at a dosage of 30 lb/1,000 ft<sup>3</sup> of the carbon tetrachloride for 24 hr indicated no injury to seeds of Pinus nigra and Picea abies. Some reduction in germination occurred with Picea sitchensis, P. glauca, and Pinus mugo. In other tests, seeds of Pinus caribaea and 2 species of Cupressus tolerated fumigation with 2 lb/1,000 ft<sup>3</sup> of hydrogen cyanide for 72 hr atmospheric pressure, or 24 hr at 25-inch sustained vacuum: Cedrus deodara was apparently injured.

In studies at Hoboken the rate of aeration of residual concentration of methyl bromide from the center of 100-lb bags of conifer seeds was not substantially increased by insertion of several perforated pipes through a bag of Pinus nigra seeds.

At Hoboken in cooperation with the Chilean Government, 4 varieties of grapes fumigated with methyl bromide in Chile, then cold treated enroute to the United States, were found tolerant to the dual treatment. Heretofore, the fumigation had been made following arrival at U.S. ports. In other tests, Rosaki grapes from Greece were found to tolerate fumigation after an intransit cold treatment. Previously it had been indicated that Spanish Almeria grapes, although not affected by fumigation, apparently would not tolerate lengthy storage.

At Hoboken hydrogen cyanide fumigation with 4 lb/1,000 ft<sup>3</sup> for 4 hr, atmospheric pressure, at 72° F apparently caused no adverse effects to imported wool samples. Fumigation with methyl bromide at an equivalent rate for khapra beetle control occasionally leaves a residual odor in wet wool. Ethylene oxide-carbon dioxide mixture (10:90) at a rate of 35 lb/1,000 ft<sup>3</sup> for 72 hr also had no observable effects on the wool.

Bruchus rufimanus survived in faba beans at Hoboken following atmospheric fumigation with methyl bromide 4 lb/1,000 ft<sup>3</sup> for 4 hr at 82° F, 6 hr at 72°, or 8 hr at 52°. Previously it had been considered that 3 lb for 4 hr at near 72° was effective. Fumigation in a 25-inch, sustained vacuum, with 3 lb for 2.5 hr at 70° or above continued to be effective. In preliminary tests, Caryedon gonagra in Cassia seeds survived atmospheric fumigation with 3 lb for 3.5 hr at near 85°, indicating that other species of bruchids are resistant to atmospheric schedules with methyl bromide.

At Hoboken small numbers of adults of a wood boring bostrichid, Sinoxylon sp., from India were killed by methyl bromide 2 lb/1,000 ft<sup>3</sup> for 16 hr atmospheric pressure at 70° F or 4 lb for 4 hr at a 15-inch sustained vacuum at 43° F. This indicates that the slightly higher schedules currently in use for other wood boring insects would be effective.

In small-scale tests at Hoboken, adults of a darkling beetle, Blapstinus sp., from California survived 2 hr atmospheric fumigation with methyl bromide 4 lb/1,000 ft<sup>3</sup> at 40 to 42° F, or 3 lb at 51 to 53°. Survival occurred with concentration-time products above those recommended for use with Chilean melons or other commodities occasionally found infested with a related species.

In preliminary studies at Hoboken an undetermined variety of strawberries tolerated fumigation with methyl bromide 3 lb/1,000 ft<sup>3</sup> for 2 hr at near 70° F or 3.5 hr at 42°.

## I. Insect Vectors of Diseases

1. Citrus Insects and Mites. Further tests with tristeza virus in Florida showed that the disease has continued to spread slowly but steadily. In a grove where 18 mature citrus trees had been inoculated artificially, field populations of aphids transmitted the virus to 6 of 38 Key lime indicator plants within the grove during a 4-year period.

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## ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

Entomology Research Division, ARS

Problem. Ornamental shrubs, flowers, and turf are damaged by the feeding of a variety of insects and mites and by diseases spread by insects. Effective and safer control measures are needed for many of these pests. Knowledge of the distribution of insect pests of these plants and information on their biology and behavior are required to provide a sound basis for the development of practical, effective, and safe control measures. Insecticidal and cultural methods of control that will not affect adversely the growing plants or natural enemies of the pests or result in objectionable insecticidal residues are needed. The nature and cause of strains of insects and mites resistant to insecticides and means of overcoming or preventing resistance require continuing investigation. The role and use of biological control agents should be more fully explored and efforts made to integrate biological, insecticidal, and cultural control methods. Use of controlled light and other physical factors as possible means of controlling greenhouse pests should be given more attention. Increased emphasis should be placed on attractants, chemosterilants, and growth or reproduction-affecting substances.

## USDA AND COOPERATIVE PROGRAM

The Department has a long-range program of basic and applied research on insect and mite pests of ornamental shrubs and flowers at Beltsville, Md., Farmingdale, N.Y., and Sumner, Wash., in cooperation with State Experiment Stations of Maryland, New York, Oregon, and Washington, and with the Crops Research Division; and on turf insects at Moorestown, N.J., and Geneva, N.Y., in cooperation with the State Experiment Stations of New Jersey, New York, and Michigan, and the Northern Utilization Research and Development, Plant Pest Control, and the Agricultural Engineering Research Divisions of ARS. Research on turf insects is also conducted under grant with the University of Florida.

The Federal scientific effort devoted to research in this area totals 8.9 scientist man-years. Of this, 1.0 man-years is devoted to basic biology and nutrition; 1.8 to insecticidal control; 0.4 to insecticide residue determination; 1.4 to biological control; 2.7 to insect sterility, attractants, and other new approaches to control; 0.7 to evaluation of equipment for insect detection and control; 0.1 to varietal evaluation for insect resistance; 0.2 to insect vectors of diseases; and 0.6 to program leadership.

In addition Federal support of research in this area under grant provides for 0.6 professional man-year devoted to insect sterility and attractants.

## PROGRAM OF STATE EXPERIMENT STATIONS

A total of 13.8 professional man-years is devoted to this area of research.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Flower Thrips. Migration studies of flower thrips based on wind vane sticky card traps showed peak flight periods during May 17-20 and June 28-July 5 at Fort Valley, Ga., and Beltsville, Md., respectively.
2. Orange Tortrix. At Sumner, Wash., when alfalfa meal was deleted from Ignoffo's cabbage looper diet all stages of growth and development of the orange tortrix slightly improved. However, when alfalfa meal was removed from Redfern's red-banded leaf roller diet, the larvae died in the first instar. Nutritionally the diets are the same except for wheat germ in Ignoffo's diet.
3. Bagworm Pheromones and Reproduction. In research under a grant to the University of Georgia, the origin of the bagworm pheromone has been shown by response of the male to be in the anterior portion of the female body.
4. Japanese Beetle. Studies at Moorestown, N.J., showed that female Japanese beetles remain in the soil for 7 to 10 days after transformation from pupae and then emerge from the soil. They begin to oviposit about 48 hours after emerging from the soil or 9 to 12 days after transformation from pupae.

A media containing alphacel, acetone powder, clover extract, protein, and a vitamin mixture sandwiched between black filter paper provided food for rearing Japanese beetle third-instar larvae to maturity. Addition and deletion of the different ingredients in the diet show that protein is needed for maintaining larvae in acetone-powder-base diets. Other ingredients that increased the percent of larvae that pupated and transformed to adults included cholesterol, Wesson's salts, vitamins, linoleic-linolenic acids, and choline chloride. The larvae feed on the cellulose in the filter paper and white paper has proved as satisfactory as black paper.
5. European Chafers. Observations made at Geneva, N.Y., showed that both males and females make more than one mating flight during their life span. Techniques were developed to determine sex of chafer larvae based on the presence of ampullae.
6. Cuban May Beetle. A method was developed to separate sexes of the Cuban May beetle under a grant to the University of Florida. Females showed a ninth tergite inside of the eighth. Two indentations resulting from this appear as dark spots. Emergence and flight patterns of this beetle are similar to those observed for the European chafer in New York. Cuban May beetles emerged from the soil at dusk when light meter readings were about 0.05 to 1.0 ft.-c. They left the trees in the early morning at similar meter readings.

## B. Insecticidal and Cultural Control

1. Aphids. At Sumner, Wash., immersion for 2 minutes in benzene hexachloride or endosulfan at 1- and .5-pounds toxicant per 100 gallons of water controlled 2 aphid species 71 days after treatment.

UC-21149, phorate, disulfoton and Bay 25141 applied in the furrow at planting time at 2 pounds actual per acre failed to control completely tulip bulb aphids 7 days after harvest (11-1/2 months after application). However, higher aphid mortality occurred in bulbs from treated plots than on bulbs from untreated plots.

At Farmingdale, N.Y., UC-21149 granules applied to the soil surface of potted Easter lilies at 3- and 6-lb/acre killed all aphids on foliage within 13 days and showed a 99% reduction after 11 weeks. UC-21149 was more effective at the 13-day and 11-week periods than demeton or oxydemetonmethyl.

2. Citrus Mealybugs. At Farmingdale, N.Y., UC-21149 granules at 5- to 20-lb per acre gave the best control of 8 systemic insecticides tested for control of citrus mealybugs on coleus.

3. Omnivorous Leaf Roller. At Beltsville, Md., Dursban and Matacil were as good or better than Zectran for control of omnivorous leaf roller larvae on roses, but Dursban was phytotoxic. Azodrin was slightly less effective than Zectran.

4. Poinsettia Pests. At Beltsville, Md., (in cooperation with the Crops Research Division) foliage and bracts of two poinsettia cultivars were uninjured by 5 weekly applications of aerosols containing sulfotep or dichlorvos and 3 sprays containing diazinon (0.25 lb), dimethoate (0.25 lb), and oxydemetonmethyl (0.25 lb). All materials tested controlled scales, mealybugs, and whiteflies, and dimethoate and oxydemetonmethyl also controlled two-spotted spider mites.

Binapacryl (0.25 lb), Hooker HRS-16 (0.25 lb), endosulfan (0.25 lb), parathion (0.25 lb), and malathion (0.6 lb) did not injure poinsettia foliage but caused necrotic spots in the bracts.

Morestan wettable powder left undesirable foliage residues and caused severe necrotic spotting of bracts. Dicofol caused reduction in size of leaves and bracts and a striking color change of bracts from red to pale pink.

5. Japanese Beetle. In field plots near Moorestown, N.J., surface applications of diazinon killed all overwintering larvae when applied during October 1966 using dosages as low as 8 lb per acre. Untreated plots averaged more than 4 larvae per square foot. Larvae were within 2 inches of ground level at time of application. Diazinon applied at 8 lb per acre late in the season following the normal oviposition period for adults can be depended on to control larvae 100%. NIA-10242 and MC-A-600 killed all overwintering larvae

present within 6 weeks when they were applied during April 1967 as surface treatments using either granular or wettable powder formulations. Larvae were near the ground level feeding at the time of application and about 6 inches of rainfall occurred during the 6-week period. Larvae in untreated plots averaged more than 5 per square foot.

At Moorestown, N.J., carbaryl in oil and naled were the quickest acting insecticides 24 hours after treating against Japanese beetles caged in a laboratory wind tunnel. Others that were very efficient included: Trichlorfon, malathion, DDVP, and ENT-27429. Mortality of beetles 48 hours after spraying showed the following order of efficiency: Carbaryl in oil, naled, azinphosmethyl, trichlorfon, dimethoate, Bidrin, and ENT-27429. At 72 hours after treatment the more effective formulations were rated in the following order: Carbaryl in oil, naled, azinphosmethyl, trichlorfon, dimethoate, Bidrin, ENT-27429, carbaryl WP, GS-13005, and diazinon.

6. European Chafer. At Geneva, N.Y., 2.5- to 5-lb Bay 37289 and Stauffer N-2790 gave 98 to 100% control of third-instar larvae within 4 weeks after exposure of larvae to soil containing 10-week-old treatments.

Ten-week-old field treatments using encapsulated diazinon at 5 lb/acre killed 74% of European chafer larvae exposed to it; whereas, less than 48% of the larvae were killed when exposed to the standard diazinon formulation.

In tests at Geneva, third-instar European chafer and Japanese beetle larvae were placed together in pots of soil treated with different dosages of insecticides. In later studies, the tests were repeated using first-instar larvae. It was found that larger dosages of insecticides were needed to control third-instar larvae of European chafer than for Japanese beetles. At least twice as much and in some instances much higher dosages were needed. It was also shown that third-instar European chafer larvae weighed twice as much as third-instar Japanese beetle. However, studies using first-instar larvae showed that both species of larvae were controlled with equal amounts (minute) of insecticides.

#### C. Insecticide Residue Determination

1. Field studies maintained at Geneva, N.Y., since 1965 show that dieldrin residues can be made inactive by applying activated charcoal. Bioassay shows that 70 to 80% of the Drosophila exposed 2 years following treatment to soil containing dieldrin at 0.6 lb/acre in 1965 were killed. Less than 0.9% of the Drosophila died when they were exposed to soil treated similarly with dieldrin then subsequently treated with 2490 lb/acre of activated charcoal.

#### D. Biological Control

1. Japanese Beetle. Two years' comparisons by Moorestown, N.J., personnel of granular and dust formulations of milky disease, Bacillus popilliae, from field plots in North Carolina show that the granular formulation is as effective for reducing Japanese beetle populations as the dust formulation.

Plots were treated in November 1964 with equal amounts of active spore dust. Spore concentrations are about equal.

At Moorestown, milky disease spores produced in vitro at the Northern Utilization Laboratory, Peoria, Ill., were found to be noninfective when fed to Japanese beetle larvae. Two other bacteria, Pseudomonas sp., supplied by the Insect Identification and Parasite Introduction Research Branch and Bacillus alvei, which is sometimes present in field-collected larvae, were also noninfective in laboratory studies.

2. European Chafer. Cooperative investigations at Moorestown and Geneva show that European chafer infested areas in western New York had an incidence of milky disease spores that ranged between 20 and 44%.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Aphids. At Sumner, Wash., aphid counts from yellow pan traps placed in aluminum foil mulched Iris plots showed a total of 76 aphids trapped from November 1966 through May 1967. Traps placed in unmulched plots for the same period caught 633 aphids. Aphid populations on Iris plants within the aluminum foil mulched plots were reduced 49% as compared to aphid populations in untreated check plots.

2. Omnivorous Leaf Roller. At Beltsville, Md., omnivorous leaf roller injury was greatly reduced on rose plants during a 70-day trapping period with a blacklight trap in a 12' X 14' greenhouse. The traps captured 390 males and 67 females. A total of 133 larvae and pupae remained on the plants in the greenhouse.

In a commercial rose greenhouse at Kennett Square, Pa., 10 blacklight traps baited with pheromone extracts of virgin females did not remove sufficient numbers of males from the greenhouse to reduce mating. Larval infestations on rose plants at the end of the study were sufficiently high to warrant chemical control.

3. Flower Thrips. At Beltsville, Md., aluminum foil mulch to repel thrips and 5 systemic insecticides to control these insects were compared for effectiveness in reducing thrips infestations on rose flowers. The mulch alone was so effective that it masked the effectiveness of the insecticides. However, flowers from UC-21149 and dimethoate-treated plants had consistently lower numbers of thrips when no aluminum was used.

4. Aphids. At Beltsville aluminum foil mulches in Unwin dahlia field plots resulted in 92% reduction of aphids trapped in yellow pans, 60% reduction of dahlia mosaic infection, and 67% increase in weight of roots at harvest.

5. Green Peach Aphids. At Purdue University, Lafayette, Ind., using a small test arena and electromagnetic energy across the wave length range of 350 to 700  $\mu$ , apterous aphids demonstrated a decrease in response to monochromatic

light as wavelength increased. When given a choice between monochromatic energy and a standard "white light" both apterous and alate aphids were more sensitive than when monochromatic light was used alone. Aphids exhibited a reversal by showing a positive response to monochromatic energy at about 600 my which is near the wave length of orange color found by other investigators to be most attractive to aphids.

6. Japanese Beetle. Analyses made by Plant Pest Control Division personnel at Otis Air Force Base, Mass., and Moorestown, N.J., personnel recorded 2.0, 0.6, and 0.4  $\mu$ g tepa remaining 1.5, 22.5, and 48 hours following treatment of Japanese beetles by dipping in 0.062% tepa for 10 seconds. At Moorestown one of 10 triazine compounds, ENT-51442, demonstrated extensive sterilization of male Japanese beetles at 1% dosage levels.

At Moorestown the presence of a male attractant in female Japanese beetles was determined by purifying gases given off in a closed chamber by female Japanese beetles.

A grid trap design was used at Moorestown to determine the behavior of Japanese beetle captures in relation to foliage. Numbers of beetles captured were increased when traps were close to foliage or vegetation.

Large scale field tests of Japanese beetle attractants in Georgia, Indiana, Nantucket Island, Mass., and New Jersey indicated that phenyl ethyl butyrate-eugenol 9:1 was generally more attractive to Japanese beetles than either geraniol-eugenol 9:1 or anethole-eugenol 9:1. In a few instances geraniol-eugenol, a more effective attractant for beetles than anethole-eugenol, captured as many beetles as phenyl ethyl-eugenol.

In Japanese beetle trap studies made on Nantucket Island in 1965 bumble bees were attracted to yellow bait traps containing anethole-eugenol in large numbers. Subsequent studies of color and lures showed that the principal attractant of these traps for bumble bees was the yellow color. White traps also attract bumble bees. Different aromatics used to attract Japanese beetles vary in their attraction of bumble bees. Bumble bees are highly attracted to anethole-eugenol but phenyl ethyl butyrate-eugenol, a better attractant for Japanese beetles, has a low attractancy for bumble bees. There was no difference in Japanese beetle catch between yellow or green traps.

About 3,000 acres on Nantucket Island were trapped to reduce Japanese beetle populations during 1965 and 1966. Twenty percent less beetles were captured in the standard blocks in 1966 than during 1965. In all traps the percent reduction was 40%. Degree of control contributed by the traps could not be fully evaluated because of varying climatic conditions in 1964 and 1965 when beetles were laying eggs. Rainfall was greater in the 1964 season. The large-scale block tests captured 12,272 beetles during 1966.

At Moorestown, N.J., a series of lures prepared by the Pesticide Chemicals Research Branch were paired with anethole-eugenol 9:1 in olfactometer and

field tests. ENT 23985-b dissolved in methylene chloride was ranked 1,940 compared to 100 for the standard. Another outstanding attractant was ENT 19663 plus eugenol which ranked 946. Six others ranked 514 to 348 in descending order when eugenol was added. In the field, ENT 21681, 33048a, and 7031 with eugenol were most attractive. Odors from ENT 7031 and 1854 were objectionable to persons living in the test area.

A satisfactory method for rapidly marking Japanese beetles used in recovery studies was developed at Moorestown. This method involved tumbling beetles in a 2-1/2-gallon metal can that contains Day Glo<sup>(R)</sup> fluorescent dust that is distinguishable in ultraviolet light. Pigments trapped in the ventral thoracic area remain visible throughout the life span of the beetles. Colors tested included: Arc yellow, fire orange, horizon blue, aurora pink, signal green, and saturn yellow. Arc yellow was readily distinguishable from the other pigments tested, but 4 of the pigments, fire orange, aurora pink, arc yellow, and signal green (or saturn yellow) are considered separable when used in the field at the same time.

7. European Chafer. At Geneva, research under cooperative agreement with the New York Agricultural Experiment Station demonstrated that gamma radiation in excess of 5,000 r would reduce longevity when applied to chafer larvae. Grubs collected in the spring were more tolerant to radiation than those collected in the fall.

#### F. Evaluation of Equipment for Insect Detection and Control

1. Japanese Beetle. On Nantucket Island there were no significant differences in the numbers of Japanese beetles captured in the Ellisco<sup>(R)</sup>, Metzger funnel, and PPC Scout traps. An experimental plastic trap developed by PPC personnel was less efficient. Bottles containing the attractant blew out and the cups used to hold the beetles captured became waterlogged, which reduced the number of beetles taken in these traps significantly.

2. European Chafer. At Geneva, N.Y., blacklight and chemical traps located 5 feet above ground level under the canopy of trees were more effective for capturing European chafer than those placed in the top of trees.

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## PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Agricultural Engineering Research Division, ARS

Problem. There is a need for studies on the precise seedbed requirements for various crops; for investigations on row spacing, placement of fertilizers, and fertilizer application equipment; for precision planting studies; and for automatic transplanting equipment.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program on planting methods and means of applying fertilizer on various crops. Approximately 1.7 scientist man-years are devoted to research on fertilizer placement and distribution equipment, seed and vegetable planting equipment, and transplanting and fertilizing equipment.

## PROGRAM OF STATE EXPERIMENT STATIONS

Problems concerned with planting of the many sizes and shapes of seed of agricultural crops, together with the introduction of fertilizers for use by these crops are under attack by many of the State Agricultural Experiment Stations. A considerable amount of this work is cooperative with the Department. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as well as solid fertilizers. In both instances, the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Vegetable Planting and Fertilizing Equipment

Four year summary of field experiments with vegetables in cooperation with the Florida station, showed yield increases of cabbage and cucumbers up to 9 percent with a two band fertilizer placement to the side and below plant or seed at time of planting, in comparison with broadcast application (common practice). Two band high-low side application (three and six inch depths) showed yield increases of green beans up to 20 percent. Rates of fertilizer (heavy, half and 3/4) showed no consistent production response. Several specially designed machines were provided - one vegetable unit now seeds or transplants, and may precision place or broadcast liquid or dry fertilizer.

During research cooperative with the Michigan station an experimental potato planter was designed and constructed in 1965-66 to study depth of planting, fertilizer placement, soil fertility, and the type and amount of compaction on the seedpiece to obtain maximum yields of quality potatoes. The 1966 results showed definite differences in the early stands by using a double "V" type press wheel; however, as the season progressed, these differences were not clearly measurable in terms of total yields. Total yields may not be a suitable measure of response since the plants surrounding skips in the row respond by developing large tubers. These tubers are often oversized, off-shaped and hollow hearted and are discounted and culled from the market.

Cooperators at the Western Washington experiment station report utilizing five of seven special seeding and fertilizing machines designed and constructed by AE. A study of sprinkler-irrigated potatoes was conducted to determine the effect of single rates of N, P, and K, (75-65-125 lbs. per acre) with the fertilizer application varied as to source and band placement. The best sources of N and K were Ammonium nitrate and Potassium sulfate. Fertilizer efficiency was improved by combining NPK materials in two bands, two inches to the side and level with the seedpiece, instead of one band.

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## CROP PEST CONTROL TECHNIQUES AND EQUIPMENT

Agricultural Engineering Research Division, ARS

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the methods which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control. It is also time consuming and costly. It is believed that with sprayers and dusters now used, often no more than 10 to 20 percent of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provides sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa, particularly for corn borer control; and at Wooster, Ohio on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and cultural, is conducted at Ames, Iowa, Columbia, Missouri, and Stoneville, Mississippi.

Aircraft application equipment is studied at Beltsville, Maryland, in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington stations and Entomology Research Division, on low growing crops. Pest control equipment research is conducted at Forest Grove, Oregon on vegetable crops.

The Federal scientific effort devoted to research in this area totals 16.2 scientist man-years per year. Of this number 1.0 was devoted to basic studies in aerosols and spray formations; 0.6 to soil fumigation; 0.3 to insect and disease control by ground equipment in vegetables and other low-growing crops; 1.0 to insect and disease control by ground equipment to fruit; 1.6 to aircraft equipment for application of pesticides to vegetables and other low-growing crops; 1.2 to aerial spray equipment for forest insect control.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack our economic crops are in progress at the several Agricultural Experiment Stations. Much of this work is cooperative with the Department.

These studies are involved in the complicated objectives of furthering the efficiency and the means for better control of insects, plant diseases, nematodes and weed problems through application of engineering knowledge on the use of aerial and ground chemical applicators for liquids and dusts, flame cultivators and mechanical devices for soil manipulation and soil fumigation.

A total of 8.6 scientist man-years is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Soil Fumigation.

1. Strips of soil were treated in 1957, in cooperation with the Ohio station, in an old cherry orchard before replants of sour cherries were set. Recent measurements show that trees grew much better and produced considerably more fruit in the treated soils.

Experimental equipment was constructed to apply granular and liquid insecticides broadcast or in the row and on the surface or mixed into the soil for control of corn rootworm larvae, cutworms, and webworm. Some insecticides used for rootworm larvae control produced increased yields. Generally, best results were obtained from insecticides incorporated in the soil. Cutworm and webworm control was inconclusive. More data is required on application equipment and techniques for control of these pests.

B. Insect and Disease Control by Ground Equipment in Vegetables and Other Low-growing Crops.

1. Equipment was prepared to meter and apply four different undiluted liquid insecticide formulations, in cooperation with the Ohio station, to vegetable crops at dosages from six to twenty-four ounces per acre. Control of green peach aphid, turnip aphid, two spotted mites, and imported cabbage worm was obtained by some of the different insecticide applications. Orchard sprays containing wettable powders at 33 to 66 times normal concentration in water were applied to apples at 0.12 to 0.24 gallon of spray per tree. Dormant oil spray was applied at 0.16 gallon per tree. Control of apple scab, European red mite, rosy apple aphid, codling moth, red banded leaf roller, and plum curculio was obtained.

Electrostatic charges were applied to dust: when dusting mint with a commercially available charger/duster, when dusting hops with a modified commercial duster, and when dusting broccoli and Brussels sprouts with a research duster. Results were inconclusive with all electrostatic charging. An automatic plate washer for aircraft spray distribution tests was developed, tested, and modified, and the operation was satisfactory. The OSU research sprayer/duster was modified to make a duster with a three-point hitch, and having simplified boom mounts.

C. Insect and Disease Control by Ground Equipment for Fruit.

1. Equipment was developed and briefly tested, in Washington, for use in mass rearing and releasing sterile male codling moth to control native infestations. Equipment included: (1) pupae sex separating machine, through size difference between sexes, using gradual larger space between two rotating incline rolls; (2) electronic sorter for separating mature from other pupae by reflection difference in infrared region; and (3) flight mill for determining vigor of moths exposed to gamma radiation - a photoelectric counter records rotations of moth attached to a pivot arm flying in horizontal circle.

Undiluted spray chemicals applied at one pint per acre on potatoes using pressure nozzles on ground machine were ineffective in controlling green peach aphid.

D. Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-growing Crops.

1. The third series of tests were completed in Oregon on boom location for helicopter spray distribution studies. These tests included: (1) ultra-low-volume (ULV) nozzle temperature studies, (2) Forest Grove electric Minispin nozzles which were fabricated and bench-tested, (3) vibrajet nozzles which

were tested and found unsatisfactory because of mechanical problems in aerial use, and (4) Plant Protection Ltd. orifice plates which were tested for the drop size spectrum. Cooperative spray studies were conducted with ENT: (1) pole beans were sprayed with malathion against the black aphid with helicopter vs fixed-wing aircraft, first results favor the helicopter; (2) lima beans were sprayed with ULV malathion in a single test for a processor with results satisfactory; and (3) broccoli was sprayed against the cabbage looper for a processor with results satisfactory. Cooperative studies were conducted with the U.S. Forest Service and a tree sampler for use from a helicopter was designed, made, and put into field use.

2. In a research project conducted under contract with the Mississippi station on equipment for application of agricultural materials from fixed-wing aircraft, the major effort has been concentrated on: (1) development of a positive-energy system for the distribution of solid materials, (2) study of the behavior of small spray particles in complex flow fields, and (3) feasibility study to determine the requirements of agricultural aircraft possibility for future designs. In the positive-energy study a full scale fluted rotor engine-driven metering device was constructed on the basis of the results of previous model tests. This was tested in the laboratory and also was ground tested after installation in the aircraft. In the small particle study, a device was constructed and tested which is capable of generating small uniform liquid particles and has the capability of isolating a single generated droplet for observation. Particle formation phenomena have been photographed. A previously reported digital computer program (for analysis of flight test data and for manipulation of flight parameters) has been converted to an analog computer program to permit continual variation of the characteristic parameters in order to determine the effect of this on the aircraft operating productivity.

#### E. Aerial Spray Equipment for Forest Insect Control.

1. Previous work at Beltsville, in cooperation with the Forest Service, indicated that electrostatically charged spray released from aircraft, generates a large residual charge on the airframe. The effects of this phenomena was investigated theoretically and proven experimentally. Results of this exploration led to a study of three techniques under which sprays might be electrically charged: technique of polarity reversal, dual power supply technique, and gaseous ion emission. Work was started on a technique to electrically atomize a low volume aerial spray.

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## CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Agricultural Engineering Research Division, ARS

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting crops and for handling of farm crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, relatively recently initiated, has already resulted in sizable cost reductions, but the potential savings for these crops and vegetables are enormous.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is being conducted at Lake Alfred, Florida; Davis and Riverside, California; in cooperation with the respective State Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Michigan; Wenatchee, Washington; and Davis, California; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots, plums, grapes, blueberries, cherries, and dates. Research on mechanical coffee harvesting is conducted in cooperation with the Hawaii Experiment Station. Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota.

The Federal engineering effort devoted to research in this area totals 25.4 scientist man-years. Of this number 5.0 is devoted to citrus and subtropical fruit; 5.3 to deciduous fruit; and 1.0 to potatoes.

## PROGRAM OF STATE EXPERIMENT STATIONS

Most of the state agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of horticultural crops. Much of this research effort is cooperative with the Department.

Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality and overall efficiency.

Current research is concerned with the diverse problems on citrus, apples, peaches, olives, apricots, cherries, prunes, cranberries, coffee, grape, pecans, cabbage, lettuce, asparagus, tomatoes, Irish potatoes, sweet potatoes, blueberries, peas and sweet corn.

During the course of these engineering investigations close cooperation is maintained with research scientists who have responsibilities for making improvements to these crops. This activity is most important in order to have machines and systems that are compatible with the new developments.

A total of 41.8 scientist man-years is devoted to this work in all crops.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Citrus and Sub-Tropical Fruit Harvesting Equipment

1. Harvesting Citrus. The decreasing availability of suitable labor for picking citrus has created a serious need for improved methods and equipment for harvesting citrus fruits. Cooperative research with the Florida Citrus Commission and the University of Florida Citrus Experiment Station was continued with headquarters at Lake Alfred, Florida. Research in California in cooperation with the University of California, growers, and manufacturers, was continued with headquarters at Riverside. Tree shape and density determine many of the design factors in developing harvest equipment. Alteration of tree properties such as surface contour, skirt height, limb structure, and foliage density might simplify the control functions necessary on a machine or improve the effectiveness of the machine operator through improved visibility. In Florida tree pruning for the shaker-catch frame harvest system is in its second season. Results indicate less tree injury from the tree shaker, slightly increased fruit removal, and more trees shaken per hour. Data will be taken one more season in this phase of the project. A search for dwarfing rootstocks and effective growth retardants are also part of this research program in California. Removing dead brush from the tree will reduce fruit injury and decay caused during

mechanical harvest. Modification which would minimize the number of major limbs in a tree has not been evaluated due to unavailability of trees. Also, modification which would minimize the amount of "interior" fruit has not been possible for the same reason. Investigations of both of these possibilities will be made next fiscal year.

2. A means of inducing abscission of some varieties of citrus fruit would increase the fruit removal capabilities of most experimental harvesting machines. The machines could also work as well at the early part of a varietal season as at the end. Intensive work was done by the Florida Citrus Commission (FCC) on the application of ethylene gas to mature citrus trees and greenhouse plants. Results were excellent for fruit abscission but unpredictable in terms of leaf abscission and root damage when soil injection methods were used. Ethylene gas is already cleared by Food and Drug Administration for citrus degreening and would be ready for immediate use in abscission if a satisfactory application method could be devised. A number of active double-bond chemicals were screened for abscission qualities as well as some halogenated salts that might prove as successful as the iodoacetic acid reported on previously. Additional contract research, administered by this project with the University of Florida, Fruit Crops Department, will be continued on the basic mechanism which causes abscission and screening of chemicals for abscission properties. In California, a greenhouse has been erected for conducting studies on the effect of electric currents on citrus trees. It has been found that placing copper or silver electrodes in the tree will kill surrounding plant tissue and the entire branch, in some cases. Stainless steel has not produced this toxic effect. Stimulated growth, related to electrical currents, has not been observed. Previous results of stimulated growth or abscission have not been substantiated in recent tests, although they may be in the future. Over 40 chemicals have now been applied to trees in field tests. Only navel oranges have shown a significant response. Ethylene, potassium iodide, naphthalene-acetic-acid, iron, and Cumeran have shown strong to weak effects on reducing the attachment force as measured by a straight pull test. In recent limb shaking tests, KI and NAA resulted in fewer fruit with stems attached but did not increase the percent of fruit removed from the tree, which averaged 93 percent.

3. In Florida the 5-year program to study the cumulative effects of citrus tree shaking on fruit yield and tree vigor is in its fourth season. Results to date look very good in early and mid-season orange varieties and grapefruit but Valencia oranges experience a drop in fruit yield the season following tree shaking due to excessive removal of the small green fruit during harvest. A "snapping shaker" is being developed which may differentiate between large mature 'Valencia' oranges and the small green fruit of next year's crop. A prototype tree shaker harvest system was built by the FCC at this location and has been used by two fruit companies in their groves harvesting mid-season oranges. Four tractor mounted inertia-type tree shakers have been built by growers using plans and design data developed in this project.

Using these shakers, the growers are shaking fruit onto the ground for hand pick-up. Work on the oscillating air blast harvest system was terminated this season because one manufacturer has built a prototype system which should be in use next season. In California analysis of limb shaker tests in Valencias and navels, reported last year, was completed. Fruit shaken from trees sprayed with 2,4-D, to tighten the fruit, had twice the decay of fruit shaken from unsprayed trees and about 1.4 times the surface injury. These studies also indicate that citrus varieties not having two crops on the tree at harvest time can be successfully harvested for processing if techniques developed by the Florida Project are applied. Methods of canopy shaking have been investigated in an effort to remove the fruit quickly and thus decrease damage. Fruit can be removed quickly by this method. Levels of damage have not been evaluated yet. Further work with vertical pulsating air for fruit removal was discontinued. Investigations may resume at a time when additional personnel are available, or other projects permit.

4. Mechanical Citrus Pickers. In Florida, development work continued on the auger-type picking spindles which contact the fruit when projected into the tree and twist it off. Two new auger shapes were tested which were not as successful as those tested in FY 66. Limited picking trials indicate that 60 to 70 percent of the fruit is removed with the present equipment in a picking time of 15 to 20 minutes per tree. This harvest method looks desirable in Valencia oranges where the augers contact the larger fruit and leave the small fruit of next year's crop. A new positioning mechanism is being built and a larger bank of augers will be built for more extensive trials.

Seven other machines belonging to private individuals or companies were evaluated. These units either strip the fruit off by raking through the tree or snap it off with rollers. None of these machines appeared economically feasible at the present time. In California, a single vacuum twist device was constructed and mounted in a positioning frame designed to hold nine similar devices. These devices can penetrate the tree canopy in a pre-set grid or be controlled by fruit sensors being developed. The equipment was field tested only enough to check the operation of the positioning frame. A complete field test will not be conducted until the devices are equipped with sensors. A fruit harvesting head using spinning rollers which comb through the tree canopy and harvest fruit by a snapping action was constructed and tested in navel and Valencia oranges. In the navel test, about 80 percent of the fruits were removed at or below the button and plugging amounted to about 1 percent. Nearly all fruit in the path of the rollers was removed. In the Valencia test, the roller head and 'Florida Auger' head were compared. Both experimental units harvested about the same percent of the fruit on the trees. About 70 percent of the fruits were removed at or below the button. Plugging was 0 percent for the auger and 2.8 percent for the roller. Fruit

surface injury and decay was similar for both units. The level of injury was much less than that experienced in limb shaking tests but the percent of fruit removed from the trees was only about 50 percent for both units. Work continued on developing a rugged, sensitive, and inexpensive fruit detector for use with the vacuum twist harvesting head. A detector using photocells, and capable of compensating for different natural light levels was constructed and tested. A prototype for field use is being designed.

5. Citrus Picking Aids. In California, the electro-mechanical power clipper designed last year was discarded after brief testing because of inherent operational problems. A pneumatic operated clipper was developed. Its cut is satisfactory, it is light weight, compact, and easily handled by the picker. The jaw design must be improved to allow easier engagement of the fruit stem before the field tests are conducted. The Power Ladder, mechanical man-positioning device, reported on last year has been redesigned by the manufacturer to allow bulk handling, working in taller trees, and improved mobility. One machine has been sold for avocado picking. Studies of human energy expenditure for hand picking citrus were conducted by a University cooperator for general picking and the component tasks involved in general picking. This identifies the 'hard' tasks. It was found that (1) carrying and setting the ladder requires nearly twice the energy per unit of time that general picking does; (2) pickers are 25 percent more efficient when picking ground fruit than during general picking; (3) picking fruit from the ladder is not appreciably less efficient than general picking. In Florida a mechanized picking platform for tree wall plantings of citrus is being tested. Preliminary picking data in a small number of trees shows no increase in picking rate in man-minutes per box but more extensive trials will be run as the fruit yield in the drastically pruned "tree walls" increases. Several fruit pick-up machines are being developed. A vacuum-type single hose machine was built and tested. A machine developed by AERD for picking up tung nuts is being modified to pick up citrus that has been hand picked and dropped or shaken onto the ground.

6. Coffee Harvesting. Coffee harvesting labor outside of the farm families is practically nonexistent in Kona, Hawaii. Since harvesting accounts for over 70 percent of the total farm labor input for coffee production the growers income is limited by the amount of coffee the farm families can harvest. Acreage has declined sharply and mechanical harvesting methods must be developed if the industry is to survive. A circular motion shaker was constructed and field tested. Vibration transmission perpendicular to the shaker arm was better, and cost was less, as compared with the linear shaker. A modified inverted umbrella and a filing cabinet type of collector were constructed. Maneuverability and pneumatic conveying were improved with the inverted umbrella unit. Mechanical problems prevented obtaining conclusive results with the filing cabinet-type collector. Rigid-frame hand-carried collectors

were successfully used in orchards with relatively even ground and uniformly spaced trees. However, drop-cloths were more satisfactory for conditions found in many Kona orchards. The following picking aids were built: (1) A hand held, balanced, reciprocating shaker; (2) a limb hung, inertia type shaker; (3) a pair of rotating, parallel, cylindrical brushes. A commercial, hand held, reciprocating shaker was obtained. Preliminary tests of these picking aids indicate that all may have excellent possibilities. A test plot was severely pruned to alter existing trees for mechanical harvesting. Results will not be available until sufficient regrowth occurs. Laboratory equipment has been assembled to study the relation between internal damping and vibration transmission. Laboratory results will be compared with theory. Because selective harvesting of ripe fruit has been inadequate, post harvest separation methods are being developed. Preliminary fruit bouncing studies show sufficient differences between ripe and green fruit to warrant further investigation. Another method uses two rollers with a tapered space between them to separate fruit by minor diameter differences. Other possibilities will also be explored.

7. Pollinization of Dates. In the past all commercial date production areas of the world pollinated the female date blooms by some hand method. Because of the shortage of labor and the fact that the harvest is now 100 percent mechanized with methods and equipment which were developed on this project, hand labor is not available for pollination. An experimental pollination program was initiated last year using both fixed-wing and helicopter aircraft to apply pollen in a dust form. All fruit produced in 12 aerial pollination plots was mechanically harvested under the supervision of project personnel. Preliminary analysis of results indicate that in several of the aerial plots the production of pollinated fruit was at least equal that of hand pollinated checks. The amount of pollen required for aerial application may be no more than for hand application but the viability should be as high as possible, i.e., good handling and storage practices are required. Because of the promising results and lack of laborers for pollination the date industry has contracted for 500 acres to be pollinated entirely by helicopter this season using the methods and equipment developed so far. In addition to the commercial acreage, four 10-acre blocks will be involved in additional application rate and frequency tests. We will also attempt to refine the application technique so that results will be improved.

8. Date Pruning, Tying etc. Dethorning, pruning, tying, and bagging are necessary operations in date production and the required labor is not available. Time studies for the tiedown operation were conducted on crews using ladders to enter the palms and using a harvesting tower to place men in the palms. Seventy-five percent of the ladder crews' time was spent in the palm tying bunches. The harvesting tower was not as efficient as the ladders and

resulted in an increase in labor requirements. Some towers are used in this operation, however, since not all of the available workers can handle the tall ladders. A support ring, made in sections, so it could be placed in the palm crown, was built and tested in an attempt to eliminate the necessity of tying each bunch to a frond stalk for support. A limited test was encouraging and various ring designs will be tried in an attempt to develop one which is inexpensive and easily installed. Time studies of the summer pruning and bagging operations were conducted. A pruning test using power saws was run. Possibly a harvesting platform designed so that power saws can be used and bags applied from the platform will decrease labor requirements and cost for this operation.

#### B. Deciduous Fruit Harvesting Equipment

1. Orchard Grading Apples. Growers store millions of bushels of apples "orchard run." A large proportion of undergrade and defective apples are stored in Controlled Atmosphere Storage (CA) and regular storage and then sorted out and sent to cider mills or other low-return outlets each year. The mobile orchard grader trials reported on in FY 66 were completed. The results show that field sorting improved the grade of the fruit stored and reduced packing and storage costs. However, it now seems unlikely that the method will come into widespread use because it requires additional help during the harvest--a time when workers are in extremely short supply.

2. Harvesting Apples for Fresh Market. Apples for fresh market must be picked without bruising the fruit and must be harvested at optimum maturity for long time storage. Labor is not available to do this and machines and/or methods which will reduce labor are needed. A comprehensive time and efficiency study comparing four machine-assisted harvesting methods and the conventional ladder-bag system was made. The results indicate that further refinements in fruit and bin handling and machine positioning will result in additional small increases in the harvest rate. Improved fruit quality can be obtained with continuous fruit conveying and careful bin filling. The fruit conveying principle developed during 1965-66 was applied to a bin filler design. The stationary filler feeds fruit into a rotating bin thus minimizing fruit bruising by reducing the velocity differential between fruit entering the bin and fruit already in the bin. Another method of conveying fruit around corners was designed and is being applied to the positive-flow conveyor principle. For use in tree wall plantings a four-picker self-propelled multi-platform prototype harvesting unit was designed and is being constructed. Each fruit is separately conveyed from the picker's hand to the stationary fruit distributor within the rotating bin. It is hoped that this unit will increase worker productivity by 40-50 percent. Also for tree wall plantings an experimental harvesting unit consisting of three horizontal banks of closely spaced metal bars (6 feet in length) were constructed and tried. In theory, the units would be pushed into the tree

from each side of the row and the apples separated from the tree by a shaker. The apples would fall (never more than a foot) onto the rods which would slope enough to carry the fruit to the outside of the tree. The tests brought to light some problems. However, the principle seems to warrant further investigation.

3. Harvesting Apples for Processing Outlets. Over 40 percent of the apples produced in the United States are processed. The critical shortage of harvest labor and the relatively low value of this fruit makes it imperative that harvest efficiency be increased. A commercial cherry harvesting machine was modified by adding decelerator strips, curtains, and flights to the conveyor. It was used in harvesting more than 12,000 bushels of Jonathan apples. The three-man crew averaged 125 bushels per hour. Five different companies processed the apples and the results showed the quality was satisfactory. A prototype kit for converting cherry harvesting equipment for use in harvesting apples will be developed and tested in FY 67. A leaf and spur removal unit was developed and proved to be very effective--so much in fact that one processor already has installed one in his packing line. An experimental roll-out type catching frame with decelerator strips was constructed and used in harvesting over 1100 bushels of McIntosh and Jonathan apples. Results were so promising that a prototype unit will be constructed and tested for 1967 season. It is hoped that it will have a capacity of 200 bushels per hour with a three-man crew and a cost of under \$10,000. A pick-up unit consisting of a metal drum studded with thin nail-like spikes was constructed and used in picking up several hundred bushels of apples. It had a high capacity and picked up over 99 percent of the apples. However, processors are afraid that dirt may get into the one hole which is made in each apple. Another type of pick up consisting of a metal drum with rubber flails which sweeps the apples onto a fixed bed plate was constructed and tested. Although it picked up the fruit, its capacity was low and it picked up considerable amounts of trash. Several other pick up principles have been tested in the laboratory and one principle--that of padded discs--looks promising and a field unit will be constructed and tested next season.

4. Harvesting Blueberries. Practically all the Michigan cultivated blueberry crop and a high percentage of the crop in other states was harvested mechanically by methods developed on this project. Last year, 21 large-capacity continuous harvesters costing \$30,000 each were used. Ten more machines costing \$30,000 and 20 more costing \$35,000 have been purchased for FY 67. Labor requirements for harvest have already been reduced by more than 15,000 workers and harvest costs lowered from 8 cents per pound to under 4 cents per pound. The objective of this research has been achieved and this project was terminated this fiscal year.

5. Harvesting Tart Cherries. Last year 28 percent of the Michigan crop of red tart cherries and 22 percent of the national crop were harvested mechanically with equipment and methods developed by this project. It is important that fruit quality be maintained if mechanical harvesting is to benefit both the grower and the processor. A new experimental electronic sorter made by the Sortex Company was evaluated. The unit has a high capacity (5,000 lbs./hr.) and sorted the cherries effectively. Michigan processors have purchased 25 units for next season. Seven destemmers, which unit project personnel helped design, were used commercially and evaluated. The destemmers had a rate of 8,000 lbs./hr. and removed about 99 percent of the stems without bruising the cherries. Several changes in design were recommended and these will be incorporated in the 30 new units being manufactured for 1967. A study of thermal properties was completed and the results made available. Further studies with the PL firmness meter developed on this project showed it to be a satisfactory method for measuring firmness. A study of bruise level and firmness showed that product yield was inversely proportional to bruise level. A study of soak water temperatures showed that there was no advantages in using 39° F. water instead of the conventional 56° F. soak water. In fact, at 39° F. firming was slower and product yield slightly lower. The effect of temperatures of the fruit as harvest on firmness, quality, and product yield were made. Results show a definite correlation between harvest temperature--the cooler the fruit the better the yield. An effort to cool fruit on the trees was made by spraying the tree and fruit with 58° F. water from an air blast sprayer. Results show that a two-minute spray cooled the fruit as much as 18° F. This method looks promising and further studies will be made.

6. Harvesting Clingstone Peaches. Although principles for mechanical harvesting clingstone peaches were developed on this project several years ago, no one has made prototype equipment. The harvesting labor supply has become serious. The major effort for this project during 1966 was in the design, construction, and testing of a cling peach harvester. The primary objectives of the program initiated were to (a) to design and test a harvester using previously developed principles considered essential for cling peaches, (b) to determine the influence of tree modification as a means of improving fruit recovery and reducing fruit injury, and (c) to determine the ability of modified trees to recover yield loss as a direct result of modification. A shake-catch harvester with several new design features was constructed, and field tested. The harvester consists of two units, one for each side of the tree, with a shaker on each unit. The machine also includes a sizer for removing small fruit, a bin filler to minimize injury to the fruit going into the bin, a blower for removing leaves, fabric catching surfaces on which dampen fruit bounce, and a maze of parallel sponge rubber tubes to decelerate fruits and minimize fruit-on-fruit impact when falling on and near the conveyor. Equipment performance was considered good although some

changes are thought advisable. The concept of a man and shaker on a tractor worked well and increased harvest rate. It permitted one person to operate the shaker and move the frame. Having a shaker on each side proved desirable. Devices used for decelerating, padding, and catching fruit were effective in preventing fruit damage. Fruit drainage from the catching surfaces needs to be improved as do the hydraulic controls for power to the axles. More flotation is also necessary on loose ground. The sizer and bin filler both need some modification but were generally satisfactory. The conveyor which was a wide low-speed unit caused no damage to the fruit. The arrangement for hand sorting defective fruit on the sizer needs further study. Harvest rate was greatly affected by the training of trees. On good trees average harvest rates of approximately 30 trees per hour were achieved. A three-to five-year study was initiated on the three tree training systems now in commercial use to determine the effect on yield, fruit damage and fruit removal. The degree of modification required to enhance the potential for mechanical harvesting is also being studied. Trees trained under one system required extensive modification involving removal of numerous major branches, whereas trees under another training system required only minor modification. Major modification resulted in considerable loss of bearing surface, but fortunately a low percentage of orchards are in this group. Hand- and machine-picked fruits were not significantly different at the orchard or cannery levels. Recovery of marketable fruit with machine harvest was within 2 to 6 percent of that with hand harvest.

7. Harvesting Pears. Many growers are planting pear trees in hedgerows. A multilevel picking platform was designed and constructed in order to test its feasibility in increasing harvesting efficiency. The multilevel unit is essentially a stairway on each side of a central conveyor; the steps being 2 x 2 feet and having a 1-foot rise from step to step. Five to six men can work on the machine. Limited tests of pruning and harvesting in hedgerows 6 feet wide indicate that the unit has potential for both operations.

8. Harvesting Sweet Cherries. In Michigan, the harvesting of the tart cherry crop is mechanized and workers are not now available for harvesting sweet cherries. In California and the Northwest labor is in short supply and mechanical harvesting methods are needed. In California a shaker was developed for use on olives and sweet cherries. This unit has a greater horsepower and stroke capacity than previous equipment and will be tested next season. In Michigan, about 150 tons of sweet cherries were harvested with tart cherry equipment and problems such as trash and fruit recovery were noted. The effect of time after harvest of brining will allow the use of bruised fruit and still result in excellent quality.

9. Rheological Properties of Wood. Mechanical harvesting is being developed for most tree fruits. Vibration and other properties of fruit tree wood and bark are useful in designing shakers and other fruit detachment devices. Trees are also being shaped and trained to fit the equipment and the forces required to bend and train limbs are needed. Elasticity and damping charac-

teristics of wood and bark were studied. A computer solution for the slow bending test was developed and published. Equations for determining dynamic and static properties using the above computer solution were derived. A tensile testing machine system in conjunction with a precision controlled temperature chamber is being constructed. The elastic modulus and the amount of internal damping in fresh Montmorency cherry bark and wood were determined. Both these properties can be used to predict the force and power to shake the tree limb as well as how far it will move. Bark sections were examined and photographed under a microscope and studies of tensile strength were made in longitudinal and tangential directions. Cambium shear strength also was measured. These values are of use in designing shaking equipment.

### C. Potato Harvesting Equipment

1. Multirow Harvesting of Potatoes. Potato harvesters are expensive and anything that can be done to increase their efficiency or use is desirable. Multirow harvesting methods are now being used by some growers. A comprehensive engineering analysis of multirow potato harvesting methods was made and a manuscript has been prepared for publication. This should provide a guide for potato growers in evaluating the potential merit of four-row indirect harvesting operations with specific combinations of yield, annual acreages, and labor requirements.
2. Bruising of Potatoes. Bruising continues to be a major problem in harvesting and handling potatoes. An instrument which growers could use to determine when potatoes were least susceptible to bruising would be of real value. Final testing of an impact instrument was completed and results show that it is an excellent instrument for measuring susceptibility to bruising. A publication is being prepared on the design and use of this instrument.
3. Dust Applicator for Seed Potatoes. Although dusting potato seed pieces has many advantages, no commercial equipment for uniform application insuring complete coverage of the surface is available. Grower-made equipment does not contain the dust to avoid air contamination in the work area. The experimental applicator described in last year's report was used under commercial conditions in treating about 3500 cwt. of seed potatoes. Two manufacturers have since made units.

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## STRUCTURES FOR CROP AND MACHINERY STORAGE AND PLANT GROWTH

Agricultural Engineering Research Division, ARS

Problem. The magnitude and scope of the crop and machinery storage problem is evidenced by the vast quantities of crops and other materials handled and stored on the farm. Annually on the farm nearly 2.5 million bushels of apples and pears and 34 million hundred-weight of potatoes and sweet potatoes are held for food, feed and seed; and other large quantities of fruits and vegetables are held for temporary storage pending marketing.

Plant growth structures can represent investments ranging from a few hundred to several million dollars depending on their nature and scale. Controlled environment growth chambers range from \$1000 to \$50,000, controlled environment greenhouses from \$2000 to \$700,000, and phytotrons from \$400,000 to \$5,000,000. During the last four years, the USDA has spent about \$500,000 per year for growth chambers. No overall expenditure figures are available.

The 1959 census showed 227 million square feet of commercial greenhouse area in the United States. Of this area, 83% is used for florist crops, 4% for nursery crops, and 13% for vegetable crops. Greenhouse produced crops equal 2% of all farm products sold.

## USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for storage and plant growth structures. The Federal effort in this research area totals 2.5 scientist man years.

## PROGRAM OF STATE EXPERIMENT STATIONS

The complicated problems associated with providing protection to the products of agricultural production as well as the machines, equipment, and service facilities which are required for such production has necessitated a continuing program of research at the State Agricultural Experiment Stations.

The current broad scale program is concerned with curing, bulk handling, and storage for onions; Irish potato and sweet potato plant production facilities and storages; controlled atmosphere storages and construction methods; designs and construction of plant growth chambers and plastic greenhouses; and many other problems.

Much of this research activity is cooperative with the Department.

## PROGRESS - USDA AND COOPERATIVE PROGRAMS

Plant Growth Structures

1. Phyto-Engineering Laboratory. Construction of the Phyto-Engineering Laboratory at Beltsville was sufficiently completed to permit occupancy in June 1966. Major effort during the remainder of the reporting year was devoted to procurement and installation of environmental control equipment. The first planned controlled - environment experiment was started during March 1967.
2. Carbon Dioxide Studies. Addition of CO<sub>2</sub> gas in plexiglass test chambers at Beltsville has given additional growth and earlier flowering in nearly every type of plant studied. Addition of carbonic acid (soda water) gave consistently negative results rather than earlier flowering and accelerated growth--as suggested from results of tests by others. Differences may be due to soil types, water hardness, solar radiation, temperature, management or a combination thereof.
3. Motion meter. Work over a period of 2 years at Beltsville has resulted in development of a highly sensitive ( $5 \times 10^{-4}$  inches change in position) motion meter for continuous detection, measurement and recording of the movements of plants during either day or night with very little disturbance to the plants. The meter has been used successfully to measure sensitive plant (mimosa) cyclic movements geotropism, and leaf thickness.
4. Portable Greenhouse Conditioning. An experimental, 16'x40' self-contained, temporary, prefabricated, plastic-on-wood- frame, greenhouse for maintaining controlled (or partially controlled) conditions for short-or-long-term experiments on fruits, vegetables, or ornamental plants that was developed last year was successfully field tested over pear seedlings being treated for Fire Blight disease. An L-P gas engine-electric generator set supplied electricity for controls, water pumps, and ventilation fan.

C. Plan Development At Beltsville, Plan No. 5980, "Plant Growth Chamber Roomette," was completed and issued by the Cooperative Farm Building Plan Exchange.

## PUBLICATIONS --- USDA AND COOPERATIVE PROGRAMS

Plant Growth Structures

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## ELECTROMAGNETIC AND ULTRASONIC ENERGY FOR INSECT CONTROL

Agricultural Engineering Research Division, ARS

Problem. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant. The promising results of a project to control tobacco hornworm with only three traps per square mile using ultraviolet radiation as the attractant in a newly designed blacklight insect trap has raised the question, "What other insects can be controlled by electrical methods and equipment alone or in combination with insecticides, chemosterilants, and biological attractants?" Production of many crops is hampered by poor, slow, or non-uniform emergence of seedlings after the seed is planted. Some electrical treatments have been found to accelerate germination and seedling emergence. If emergence in the field can be speeded up and better uniformity obtained, weed control can be much more effective, with resulting increased efficiency in production of crops. Treatments also increase the percentage of germination for some seeds and would therefore enable the establishment of good stands with lower investments for seed. Further, uniform emergence tends toward more uniform saturation and increased practicability of once-over harvest programs.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the State Experiment Stations. Research on electrical and physical methods of vegetable insect control and light trap design is conducted in California and Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station.

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination are in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperative help on some phases of studies was furnished by the Crops Research Division, ARS, the Asgrow Seed Company, the Agricultural Engineering Departments of the University of Idaho and Texas A & M University, and others.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 11.3 scientist man-years; of this number 5.8 are devoted to electric traps for insect survey, destruction and control; 0.8 to components and design of electric insect traps for survey and control; 2.0 to sonic and ultrasonic energy for insect control.

### PROGRAM OF STATE EXPERIMENT STATIONS

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production. Investigations in progress, many of which are cooperative with the Department, include the evaluation of the use of light sources of various wavelengths for attracting and collecting insects which infest many of our economic crops.

### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

#### A. Electric Traps for Insect Survey, Destruction and Control

##### 1. Electric Traps for Vegetable Insects

Applications of electric light traps for control of vegetable insect pests were primarily studied at Lafayette, Indiana, Riverside, California, and Red Rock, Arizona.

Activities at Lafayette, Indiana, were cooperative with the Purdue University Agricultural Experiment Station through the Departments of Agricultural Engineering and Entomology, and the Indiana Electric Association continued to give partial financial support for the program. The H. J. Heinz Company, Plymouth, Indiana, and Osborn Seed Service, Burr Oak, Indiana, both commercial producers of cucumbers, cooperated with investigations to determine the effectiveness of electric light traps in controlling striped and spotted cucumber beetles.

The striped, Acalymma vittatum (F.), and the spotted, Diabrotica undecimpunctata howardi Barber, cucumber beetles are the principal insect pests of cucumbers in Indiana, causing damage directly from the time the plants emerge until they die by feeding on the roots, stems, leaves, blossoms, and fruit; and indirectly in inoculating the plants with, and by spreading, the causal organism (Erwinia tracheiphilus) of the bacterial wilt of cucurbits. Prior research on protecting cucumber plants in small vegetable-garden plots conducted from 1958-63 indicated that, use of light traps might reduce the number of insecticide applications required in commercial production.

Experiments to investigate the area range of effectiveness of electric insect traps used with and without a complementary insecticide for protecting cucumbers in large commercial plantings from striped and spotted cucumber beetles were begun in 1966 near Plymouth, Indiana. Effectiveness of treatments

(light trap + no insecticide, and light trap + insecticide) at various distances from traps was evaluated through incidence of wilt and through yield. Six traps having five 15-watt blacklight lamps as attractants were used in each of 2 fields. These traps had the lamps mounted over a funnel-fan arrangement that directed the insects down into a barrel containing diesel fuel. Rows of cucumbers were left unsprayed at various distances from the traps and these plants were compared with adjacent sprayed plants.

Plant wilting in plots 460 and 600 feet from the traps was first observed about 3 weeks after the beetles began feeding. In one field, at distances 110 feet or less from traps, the progression of wilt was delayed about 4 weeks. In the other field, at distances 175 feet or less from traps, the progression of wilt was delayed 1 to 2 weeks. In the first field, 13 percent of the plants in plots 11 and 110 feet from the traps were dead from wilt on September 7, while 46 percent at 460 feet were dead. In the other field, 29 percent of the plants in plots 15, 95, and 175 feet were dead from wilt on September 7, while 32 percent at 600 feet were dead. This substantiated prior findings indicating the effect of traps to be negligible beyond 125 feet. No real yield differences at different distances were observed, although fewer plants were producing cucumbers in the distant plots as the season progressed. Severe drought occurred, so if plants had survived and harvest continued longer, as is normal, differences would probably have become significant. There were no evident differences in incidence of wilt or yield between sprayed and unsprayed plants at any distance.

The responses of the striped and the spotted cucumber beetles to electric traps, as affected by the presence of diesel fuel in the collection chamber and by environmental factors, were investigated. The presence of either diesel fuel or calcium cyanide in collection chambers did not effect the catches of cucumber beetles, but identifying the diesel-soaked insects was very difficult because colors and details were obscure. Studies concerning the responses of cucumber beetles to light traps as related to factors influencing flight showed that peak flight occurred from 9 to 10 p.m. Secondary peaks occurred from 4 to 5 a.m. Temperature was found to be the most important factor influencing collections. Maximum collections were made when air temperatures were between 60° and 75° F. Collections were reduced with higher and lower temperatures. Wind velocity had little effect on the flight of the striped beetle; however, the spotted cucumber beetle had increased flight activity when wind ranged between 6 and 9 knots per hour.

Research at Riverside, California, was continued in cooperation with the University of California and Entomology Research Division (ENT) ARS. The work consisted of testing various preparations of synthetic sex attractant (pheromone) for the cabbage looper, Trichoplusia ni, developing a technique for dispensing the active pheromone; and installation of a large trapping experiment in Arizona.

Several formulations of synthetic pheromone were compared for effectiveness in increasing catches of male cabbage loopers in blacklight insect traps. The formulations were prepared by the Pesticide Chemicals Research Branch, ENT, ARS. The first formulation was used to test various dispensing techniques. Of those methods tried, the best results were obtained by treating 40 grams of sand with 0.1 grams of pheromone. The sand-pheromone mixture was placed in a beaker and attached to the trap. This dispenser increased catches of males for 42 days in the field.

Several trap designs were tested using the pheromone without blacklight. The only trap that was effective was an electrocutor grid and it killed nearly as many as were caught by a blacklight trap.

Based on previous experiments, a large field trapping experiment was initiated on an isolated lettuce ranch near Red Rock, Arizona. Approximately 2400 cultivated acres are being trapped and all traps are equipped with pheromone dispensers and two 15-watt blacklight lamps. The ranch is divided into 80-acre fields which are 1/4 by 1/2 mile, with roads and irrigation canals around each field. There are approximately 400 traps located at 330-foot intervals along the roads separating the fields. The electrical distribution system was buried underground and required approximately 26 miles of cable. The initial installation cost was approximately \$40 per acre. If the life expectancy of the installation is 10 years, the system should operate for \$7 per acre per year for all costs. The grower presently spends as much as \$100 per acre of crop for chemical control of insects. Evaluation of results will be based upon analysis of collections from approximately 10 percent of the light traps plus egg and larval counts on crops inside and outside the area. Operation began in February 1967. The field experiment at Red Rock will continue, with contributing fundamental research being continued at Riverside.

## 2. Electric Traps for Fruit and Nut Insects

Cooperation at Yakima, Washington, was continued with ENT, ARS, in preliminary investigations of usefulness of light traps for control of codling moth, Carpocapsa pomonella. Facilities were equipped for active cooperation and a professional scientist reported for duty in April 1967.

At Albany, Georgia, cooperation with ENT, ARS, was also continued on studies of pecan insects, particularly the hickory shuckworm, Laspeyresia caryana (Fitch), the pecan leaf casebearer, Acrobasis juglandis (LeBaron) and the pecan nut casebearer, Acrobasis caryae Grote. An experiment for evaluating the effectiveness of light traps for control of these species has been initiated in an isolated 10-acre pecan grove using approximately three light traps per acre. A professional scientist is being sought for this activity.

## B. Components and Design of Electric Insect Traps for Survey and Control

Of several trap design features tested at College Station, Texas, near-ultraviolet output of attractant lamps affected the trap catches more than any other single factor. The number of moths caught was found to be nearly directly proportional to the total near-ultraviolet output of attractant lamps. Traps with emissions ranging from 0.0 to 20,000 milliwatts of near-ultraviolet output were tested. Funnel size was another factor that appeared highly significant, especially as related to catches of insects in general. An increase in funnel diameter resulted in an increase in numbers and/or weight of insects caught. Funnel diameters tested ranged from 14 to 60 inches. A trap spacing experiment using 15-watt blacklight lamps showed that catches increased in almost direct proportion to numbers of traps operated regardless of spacing. Trap spacings of 450, 225, 150, and 112.5 feet were compared. These results indicate optimum spacing for these traps is something less than 112.5 feet. Further investigation will be made of the influence that total near-ultraviolet output has on trap catches, with particular emphasis on determination of maximum effective output per trap. Funnel size studies will also be continued.

At Oxford, North Carolina, traps modified by the addition of red, green, or white baffles or lamps were not, in general, more efficient in capturing insects than those not modified.

In field experiments at Chatham and Blacksburg, Virginia, light traps with fans below the lamps did not catch more hornworm moths than traps without fans. This condition existed in 1965. Again this year, more corn earworm, Heliothis zea (Boddie); cabbage looper, Trichoplusia ni (Hubner); and armyworm, Pseudaletia unipuncta (Haworth), moths were captured in the traps equipped with fans than in traps without them. A similar trend was indicated in the capture of budworm moths, Heliothis virescens (Fabricius). As found in prior experiments, light trap catches were increased by increasing the number of 15-watt lamps from one to four per trap or by changing from a 15-watt to a 30-watt lamp, but the increased catches were less than directly proportional to the increased lamp wattage. No significant differences were found in catches by traps equipped with new lamps and by those equipped with lamps that had operated for a period equivalent to two seasons.

The research relating to insect trap design was conducted on Kentucky Agricultural Experiment Station farms located near the University campus. Three replications of six different designs were tested. These designs were:

1. A standard one-lamp gravity trap.
2. A one-lamp trap with suction fan rated 450 c.f.m.
3. A three-lamp gravity trap with 3 vanes - center open.
4. A three-lamp gravity trap with 3 vanes - center closed.
5. A four-lamp gravity trap with 4 vanes - center open.
6. A four-lamp gravity trap with 4 vanes - center closed.

The results of operating these traps for 6 weeks showed that the trap with fan had the poorest operating efficiency of all, which had been suspected from last year. The trap with four lamps and an open center rated best of all types and statistically was better at the 5-percent level than all except the trap with four lamps and a closed center.

In Indiana activities concerning the use of insect traps for survey purposes included assisting cooperators throughout the North Central States with general insect surveys and participating in North Central Regional Project No. 67, Migration of Aphids and Noctuids. Cooperative activities with the Plant Pest Control Division (PPC) and the Entomology Research Division (ENT) were also continued. Survey entomologists in the North Central States use light traps to obtain data on the abundance of insects of economic importance. This information is sent to the Cooperative Economic Insect Report for release to interested entomologists and producers. Participation in North Central Regional Project No. 67, Migration of Aphids and Noctuids, was limited to assisting Purdue cooperators with installation and maintenance of trapping equipment for corn earworm migration investigations. The 20 light traps used were located throughout Indiana. Data obtained provided valuable information to extension workers and farmers as to the need for and time to apply chemical controls.

Use of blacklight traps for quarantine surveys for European chafer, Amphimallon majalis (Razoumowsky), and for detection surveys at ports of entry was again expanded by PPC, with additional chafer infestation areas located. Assistance was again provided to the Northeastern Region of PPC concerning equipment problems of the European chafer program and continuing cooperation was provided ENT on the fundamental European chafer research program at Geneva, New York.

C. Radiofrequency and Glow-discharge Energy for Insect Control and Treatment of Seed and Plant and Animal Products

Studies relating to potential uses of radiofrequency (RF) energy for insect control and to the effects of glow-discharge and RF radiation on seed and plant products have been continued.

Vegetable and Ornamental Seed Studies

In work cooperative with CR, ARS personnel at Texas A & M University, germination of mesquite and huisache seed was improved by RF treatments, but these treatments failed to produce any germination in yaupon seed. In preliminary work, the germination of huisache seed was not improved. Further experiments will be conducted to continue the study of effectiveness of different combinations of variables in reducing hard-seed content and improving the germination of horticultural crop seed.

## PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Electric Traps for Insect Survey, Destruction, and Control

Hartsock, J. G., Deay, H. O., and Barrett, J. R., Jr. 1966. Practical application of insect attraction in the use of light traps. Bull. Entomological Society of America. 12(4):375-377. December.

Henneberry, T. J., Howland, A. F., and Wolf, W. W. 1967. Combinations of blacklight and virgin females as attractants to cabbage looper moths. Journal of Economic Entomology. 60(1):152-156. February.

Sonic and Ultrasonic Energy for Insect Control

Agee, H. R. and Webb, J. C. 1966. An ultrasonic speaker for studies of the acoustic sensitivity of tympanate moths. USDA, ARS 33-116. December.

Radiofrequency and Glow-discharge Energy for Insect Control and Treatment of Seed and Plant and Animal Products

Nelson, S. O. 1966. Electromagnetic and sonic energy for insect control. Transactions of ASAE. 9(3):398-405.

Nelson, S. O. and Seubert, J. L. 1966. Electromagnetic energy and sound for use in control of certain pests. USDA, ARS 33-110. July.

## ELECTRIC AND SOLAR EQUIPMENT FOR ENVIRONMENTAL CONTROL

## Agricultural Engineering Research Division

Problem. Special controlled environments are necessary for the proper conditioning of crops like sweet potatoes, and are extremely effective in maintaining the quality of stored fruits and vegetables. Current scientific and economic developments indicate that production of vegetables and flowers in the future may require complete control of soil, light, and atmospheric conditions. Engineering problems associated with the application of light to plants have increased in recent years with the need for growth rooms for research and commercial use of light for growing crops.

## USDA AND COOPERATIVE PROGRAM

A program at Beltsville has been established whereby engineers from the Agricultural Engineering Division cooperate with Crops Division scientists on basic studies of light and thermal environment and their relation to plants in growth chambers.

Equipment for the application of carbon dioxide to plants is under development at Beltsville and at Kansas State University in cooperation with the Departments of Agricultural Engineering, Horticulture and Physics. Performance characteristics of equipment are being studied for maintaining environment for conditioning potatoes for processing in cooperation with the Departments of Agricultural and Chemical Engineering, Horticulture and Plant Pathology of the University of Minnesota and the Market Quality Research Division and the Transportation and Facilities Research Division, ARS, East Grand Forks.

The Federal scientific effort devoted to research in this area totals 5.6 scientist man-years; of this number 2.6 are devoted to plant environment equipment.

## PROGRAM OF STATE EXPERIMENT STATIONS

The State agricultural experiment stations are engaged in extensive basic and applied research to extend the advantages of controlled environment to all phases of agriculture in order to obtain maximum economic growth, production, product preservation, and product quality. Studies of the possibilities for use of solar energy as well as electric energy to achieve the broad scale objectives are a part of the total program. Among the several investigations involved in these programs are determination of the effects of soil, light, and atmospheric conditions on plants; and temperature, humidity and gases on stored products.

A great portion of this research is cooperative with the Department.

A total of 4.9 scientist man-years is devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Plant and Product Environmental Equipment1. Carbon Dioxide Fertilization

At Manhattan, Kansas, chrysanthemums were misted with tap or carbonated water or supplied additional CO<sub>2</sub> from a gas burner in continuing tests in commercial-type 20' x 40' glass greenhouses. During the winter and early spring the house with the natural gas burner produced the best plants. In the late spring, the plants misted with carbonated water had the best growth. During the summer and fall seasons the plants misted with carbonated water showed improved growth over those misted with tap water. The natural gas burner may not be used during the summer and fall seasons due to increased ventilation requirements.

The traveling nozzle produced a more uniform dispersion of the mist over the entire bench width and proved superior to a plastic hose with nozzles spaced at about 2-foot intervals down the center of the bench.

Leaf lettuce plants were studied in plant growth chambers. In one chamber the plants were misted with carbonated water while in a check chamber they received no mist. Room air was circulated through both chambers and then exhausted to the atmosphere. Four temperatures were studied in this first series of tests, from 10° C. to 33° C. in steps of about 7.5° C. Results have not yet been analyzed.

Carbon dioxide concentration was monitored in both the greenhouses and the plant growth chambers. Leaf temperatures and light intensity were periodically measured to assure approximately equal radiation on the plants in both chambers.

At Beltsville, Maryland, tests on the use of carbonated water to furnish additional CO<sub>2</sub> to plants were discontinued as consistently negative results were obtained instead of earlier flowering and accelerated growth as reported from Kansas. The difference may be due to soil types, water hardness, solar radiation, temperature, management, or a combination of these factors. The addition of CO<sub>2</sub> gas in the plexiglass test chambers has given additional growth and earlier flowering in nearly every type of plant.

2. Plant Growth Lighting, Radiation, and Instrumentation

At Beltsville the Phyto-Engineering Laboratory was completed and occupied although all of the auxiliary services were not installed. The construction, moving, and setting up of equipment required a large percent of the staff effort. The first planned controlled-environment experiment was started during March 1967.

The motion meter was used by the Plant Physiology Pioneering Laboratory to measure cyclic movements of mimosa, a light-sensitive plant. It was also used by them to study geotropism. A working model instrument was developed from the motion meter to measure leaf thickness to be used in CR hay breeding investigations.

### 3. Electric Equipment for Soil Warming for Plant Growth

Experimentation to study the potential use of electric heating cables under ornamental shrubs was continued cooperatively with the Purdue Department of Horticulture. The objective is to eliminate winterkill due to desiccation and thereby extend the growing period for certain temperature-critical evergreens. Although the rootzone of the plants were kept thawed and winterkill was reduced, desiccation still occurred.

### 4. Environmental Equipment for Conditioning Potatoes for Processing

In Minnesota, cooperative work is underway to evaluate the effects of different storage temperatures on tubers used for processed flakes and to develop a frost-free refrigeration system for maintaining low storage temperatures during an approximately 9-month storage period. The same experiments were repeated for several years to minimize differences due to varying environmental conditions from one growing season to another. Variety differences in reaction to storage temperatures show up. Some varieties have a short dormancy period and start sprouting if held at 50° F. Observations indicate pressure bruising problems when the temperature in bins of high depth is elevated to 65° F. for conditioning.

## PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

### Plant and Product Environmental Equipment

Bailey, W. A., van der Zwet, T., Klueter, H. H., and Krizek, D. T. 1967. Plastic greenhouse with partial environmental control for horticultural research. Proceedings Seventh National Agricultural Plastics Conference.

Cathey, H. M., Klueter, H. H., and Bailey, W. A. 1967. Indoor gardens for decorative plants. The American Horticultural Magazine. pp. 3-12. January.

Cathey, H. M., Klueter, H. H., and Bailey, W. A. 1967. Indoor gardens for decorative plants. USDA Home and Garden Bulletin.

